ECONOMIC BOTANY

DEVOTED TO APPLIED BOTANY AND PLANT UTILIZATION

The Utilization of Marine Algae in Tropical South and East Asia

JACQUES S. ZANEVELD

Seed Protein Sources—*Amino Acid Composition and Total Protein Content of Various Plant Seeds*

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Retamo Wax, Living Telegraph Poles

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The Utilization of Marine Algae in Tropical South and East Asia [1]

A review of the seaweed resources of South and East Asia may promote current research on the economic marine algae of this part of the world. The algae have to be regarded as very important in the future economy of a crowded world.

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From ancient times till the beginning of the 19th century the occidental and oriental peoples differed largely in opinion with regard to the importance of marine algae. Whereas the Greeks and Romans spoke about "dejecta villior algae," the orientals, even by the time of Confucius, considered seaweeds a food of great delicacy. Especially the Chinese, the Japanese, the Filipinos, and the Hawaiians are known as phycophages. Moreover, in the East, algae are used not only as food but also for many other purposes.

After 1800 the industrially-minded westerners changed their opinion and in several countries exposed to the Atlantic a seaweed industry was started and became prosperous, especially in the 20th century. As a result of this the literature on the economic applications of marine algae increased considerably in the last forty years.

> *"Indeed, the seaweeds are not finding repose in this generation; for day by day, the scientists and industrial workers are developing new uses for them in every walk of life."*
>
> (Florence Meijer Chase in Ann. Rep. Smith. Inst. p. 451. 1942.)

[1] This article is largely a reprint of "Economic Marine Algae of Tropical South and East Asia and Their Utilization," Sp. Publ. No. 3, Indo-Pacific Fisheries Council, FAO. Permission to reprint is gratefully acknowledged. Illustrations were made possible by support from the Seaplant Corporation, New Bedford, Massachusetts.

However, a review of the seaweeds used in the islands of the Malay Archipelago does not exist, although Burkill in his invaluable work, "The Economic Products of the Malay Peninsula" **31**, did not restrict his remarks on the utilization of algae to the peninsula proper.

On account of this the present author **155**, **157** published a survey of marine Cyanophyta, Chlorophyta, and Phaeophyta used in "Malaysia." a term (Lam **74**, Steenis **124**, Zaneveld **152**) indicating Indonesia, the Philippine Islands, and the Malay Peninsula.

A third part consisting of the Rhodophyta and a bibliography only appeared in mimeographed form in The Technical Papers of the Indo-Pacific Fisheries Council, October, 1952 (Zaneveld **159**). The Sub-Committee on Seaweeds of the Indo-Pacific Fisheries Council was of the opinion that it would be very useful to workers in this field to have the three papers available as a single publication. Therefore, on the request of the Subcommittee the papers were revised and extended to include other tropical regions of South and East Asia, i.e., India, Ceylon, Cambodia, and the Hawaiian Islands (Zaneveld **160**).

The writer is greatly indebted to Dr. Cecil Miles, then Secretary, Indo-Pacific Fisheries Council, Bangkok, Thailand, for gathering data from the Member

Governments, and to these Governments for furnishing subsequent amendments and notes.

On request of the Editor of Economic Botany the I.P.F.C.—Special Publication of this paper now appears in Economic Botany. By courtesy of the Editor and with the financial aid of the Seaplant Corporation, New Bedford, Massachusetts, for which the author wishes to express his sincerest thanks to the Research Director, Dr. Leonard Stoloff, a number of illustrations could be included and the paper has been totally revised. Therefore, the paper now appears under a new title. I wish to express my sincere thanks to the Editor, Dr. D. J. Rogers, for taking the initiative of having the original paper reprinted.

In order to make the present survey more easily accessible to non-botanists, the genera and species are not arranged taxonomically, but alphabetically.

The literature mentioned for the individual species and varieties concerns only the original description, the place

TABLE I

Division	Order	Family	Genus
CYANOPHYTA (MYXOPHYCOPHYTA)	Nostocales	Nostocaceae	*Nostoc*
CHLOROPHYTA	Ulotrichales	Ulvaceae	*Enteromorpha*
	Ulotrichales	Ulvaceae	*Ulva*
	Cladophorales	Cladophoraceae	*Chaetomorpha*
	Siphonales	Caulerpaceae	*Caulerpa*
	Siphonales	Dasycladaceae	*Acetabularia*
	Siphonales	Codiaceae	*Codium*
PHAEOPHYTA	Ectocarpales	Encoeliaceae	*Chnoospora*
	Ectocarpales	Encoeliaceae	*Hydroclathrus*
	Dictyotales	Dictyotaceae	*Dictyota*
	Dictyotales	Dictyotaceae	*Padina*
	Fucales	Sargassaceae	*Sargassum*
	Fucales	Sargassaceae	*Turbinaria*
RHODOPHYTA	Bangiales	Porphyridiaceae	*Porphyra*
	Nemalionales	Helminthocladiaceae	*Liagora*
	Gelidiales	Gelidiaceae	*Gelidiella*
	Gelidiales	Gelidiaceae	*Gelidium*
	Cryptonemiales	Grateloupiaceae	*Grateloupia*
	Cryptonemiales	Grateloupiaceae	*Halymenia*
	Gigartinales	Solieriaceae	*Agardhiella*
	Gigartinales	Solieriaceae	*Eucheuma*
	Gigartinales	Rhabdoniaceae	*Catenella*
	Gigartinales	Hypneaceae	*Hypnea*
	Gigartinales	Phyllophoraceae	*Gymnogongrus*
	Gigartinales	Gracilariaceae	*Gracilaria*
	Gigartinales	Gracilariaceae	*Corallopsis*
	Gigartinales	Gracilariaceae	*Gelidiopsis*
	Gigartinales	Sarcodiaceae	*Sarcodia*
	Rhodymeniales	Rhodymeniaceae	*Rhodymenia*
	Ceramiales	Delesseriaceae	*Caloglossa*
	Ceramiales	Rhodomelaceae	*Bostrychia*
	Ceramiales	Chondrieae	*Acanthophora*
	Ceramiales	Laurenciaceae	*Laurencia*

where the recombination of the specific epithet was introduced, and the publications dealing with the economic application of the species involved. Not included are references to purely taxonomic and ecological matters.

The classification of the seaweeds here enumerated is in accordance with Fritsch **44** (Table I).

The number of marine algae used in one way or another in the region under discussion is undoubtedly much greater than would be gathered from the present paper. This is due to the lack of references in literature to the many species utilized in Japan, China, the mid-Pacific islands, and Australia and also occurring in the region under consideration, rather than to these species not being used. Besides, the identification of the species mentioned in literature could not be verified, so that it is possible that other species than those cited may have economic applications.

It is therefore desirable that taxonomic investigations, the background for all scientific and industrial biological work, be continued and promoted.

Nevertheless, it should be remarked that the utilization of marine algae as human food, particularly in the Malay Peninsula and in Indonesia, seems nowadays by no means as general as one would suppose when reading the earlier authors like Rumphius **114** and Von Martens **88**.

It is hoped that this paper will contribute materially to current research on the economic marine algae of this part of the world and aid in solving marine algal problems which the author regards as very important in the future economy of a crowded world.

CYANOPHYTA (MYXOPHYCOPHYTA)

Note: A careful study was made by Suringar of the use in Japan of an edible cyanophyte not listed below, viz. *Phyllo-derma sacrum* Suringar (Okamura **102**). Some items may be recapitulated here as the alga probably occurs in Malaysia too. The plants are gathered from the natural growing places and thoroughly washed with water. All epiphytes and other adhering matter are removed with pincers, and then the weed is chopped up. After that, the mass is crushed and made into a paste by kneading it with a trowel. Then this paste is spread over unglazed tiles in the sun. When dry it is peeled off the tiles in thin paper-like sheets. For use, these sheets are cut into small strips and soaked in water until they swell up, when they are ready for use.

As I was informed by Mr. W. H. Schuster, who was in 1950 Adviser on Fisheries, Djakarta, the vernacular name "keklap" is used by the Javanese people to indicate the free floating cyanophyte colonies. These colonies mainly consist of *Oscillatoria* species, but *Nostoc* species are sometimes also extant. The colonies, including the detritus, are eaten by fish.

Nostoc Vaucher

Nostocales, Nostocaceae

The dense thallus is composed of numerous intertwined, contorted filaments with thin walls and a thick, gelatinous sheath. Gelatinous thallus extremely variable as to size and shape, solid or hollow, floating free or attached. Growing in sea, brackish and fresh water, or on surface of damp soils.

Note: A fair amount of proteins is present in *Nostoc* species (Burkill **31**, 1561).

Nostoc commune Vaucher

Vernacular name: djamur batu (Java)

Literature: **134**, 822. **27**, 203. **14**, 156 (no species mentioned; "blue weeds" only). **31**, 1561.

Distribution: Cosmopolitan.

Use: According to a note on a label of a specimen extant in the Leiden Her-

barium it is sometimes eaten in Java. (Communicated by Miss J. Th. Koster, Rijksherbarium, Leiden, Netherlands.) Okamura **102** and Burkill **31** both mention that the species is frequently eaten by the Japanese and the Chinese. The Chinese use seaweed jelly made from several species of *Nostoc* or fah-tsai.

CHLOROPHYTA

Acetabularia Lamouroux
Siphonocladiales, Dasycladaceae

A genus of lime-encrusted plants confined to warm waters. The algae have the appearance of a slender toadstool, consisting of an erect axis bearing one or more whorls of forked, sterile laterals with a single fertile whorl at the apex. The delicate plants are seldom over a few cm. high. Growing in shallow water of the littoral region where the plants are anchored on stones, rocks, etc., by means of richly branched rhizoids.

Acetabularia major Von Martens

Vernacular names: gembur batu, kedji, kedji beling, ketjibling, petjah beling (All Javanese and Sundanese names).

Literature: **88**, 25, pl. 4. f. 3. **25**, 54. **26**, 39. **13**, 15, 16. **63**, 36. **31**, 28.

Distribution: Indonesia: Java (Djapara). Japan, Philippines, Siam.

Use: The species is used on the north coast of Java as a remedy for gallstones, renal calculi, and stones in the bladder. This is probably due to the ability of the rhizoids to secrete acids (Boorsma **26**). An annotation given on the label of a specimen extant in the Buitenzorg Herbarium mentions that after chewing the alga for two minutes a piece of glass was completely masticated without any damage to the mouth and tongue. (Beumée **13**, 15, 16.) Burkill **31**, 28 also remarks: "There is no reason to regard it as of value. Its employment is by homeopathic magic."

Caulerpa Lamouroux
Siphonales, Caulerpaceae

The colorless rhizoids are attached to sand or to dead pieces of coral. The rhizoids give rise to a great number of green shoots, which are simple and phylloid, or exhibit axes bearing ramuli of various shapes. This is a large, widely distributed genus in the tropics. Most of the species occur in the shallow water of the littoral region below low tide level (baso- and semi-littoral belt, Zaneveld **151**), preferably in lagoons protected by coral reefs.

Note: According to Okamura **102** the plants of *Caulerpa* are not dried but preserved in salt when used for human food.

Caulerpa peltata var. **macrodisca**
(Decaisne) Weber-Van Bosse

Vernacular name: lata (Bangka).

Literature: **77**, 145, pl. 17, 3 f.2. **38**, 336 (sub nom. *Chauvinia macrodisca*). **138**, 376. **64**, 319. **36**, 129. **128**. **63**, 35. **31**. 498.

Distribution: Ceylon. Indonesia: Bangka, Celebes (near Makassar), Postiljon I., Djedan I. Philippines. Polynesia.

Use: This variety is eaten in Bangka. In Luzon (Ilocos and Cagayan Provinces) it is used raw as a salad.

Caulerpa racemosa
(Forskal) Weber-Van Bosse

Vernacular name: lelato (Lombok).

Literature: **43**, 191 (sub nom. *Fucus racemosus*). **138**, 357. **142**, 264. **128**. **63**, 35. **113a**, 35. **31**, 498. **135**, 100.

Distribution: Ceylon. India: Pamban area. Malay Peninsula. Philippines. Indonesia. Atlantic (incl. Mediterranean). Widely distributed.

Use: Quite edible, of a rather pleasant taste with a piquant tang; especially eaten in eastern Malaysia. Velasquez **135**, 100 states that this species is important in the diet of the Philippines.

It is planted in large containers and, when harvested, has to be sold within a few hours of collection; otherwise it deteriorates.

Caulerpa racemosa var. **clavifera** (Turner) Weber-Van Bosse

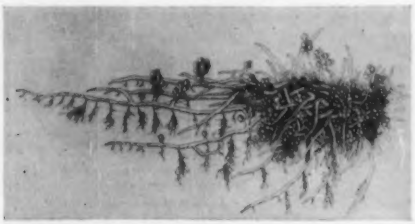

Fig. 1. *Caulerpa racemosa* var. *clavifera*: habit, X 0.5 (after Boergesen, 1907).

Vernacular name: lai-lai (Ternate: Tawali-ketjil).

Literature: **132**, pl. 57 (sub nom. *Fucus clavifer*). **138**, 361. **88**, 141 (sub nom. *Chauvinia macrophysa*). **128**. **64**, 319. **63**, 35. **31**, 498.

Distribution: Ceylon. Malay Peninsula. Atlantic, (excl. Mediterranean). Widely distributed.

Use: According to Von Martens the plants are eaten as a desert after a rice meal. In Makassar (Celebes) the variety is sold in the native market. It is used raw and cooked. It is also eaten in the island of Guam (Safford **115**, 177).

Caulerpa racemosa var. **laetevirens** (Montagne) Weber-Van Bosse

Vernacular name: bulung buni (S. Bali).

Literature: **98**, 16, pl. 6, f. 1. (sub nom. *C. laetevirens*). **138**, 366. **64**, 319. **128**. **63**, 35. **31**, 498.

Distribution: Ceylon. Indonesia: S. Bali, Ceram-Laut I., Kei I., Damar I. Philippines. Friendly I., Australia. West Indies.

Use: This variety is eaten in southern Bali.

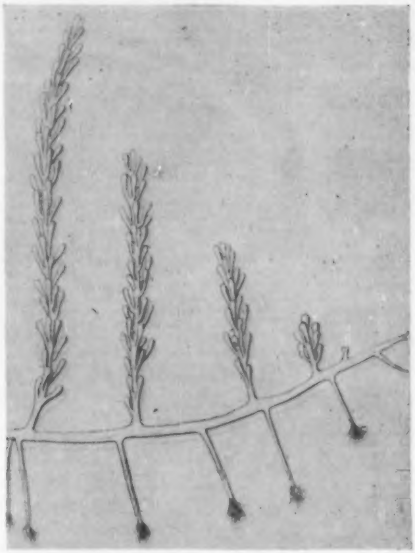

Fig. 2. *Caulerpa racemosa* var. *laetevirens*: habit, X 0.5 (after Boergesen, 1907).

Caulerpa racemosa var. **uvifera** (Turner) Weber-Van Bosse

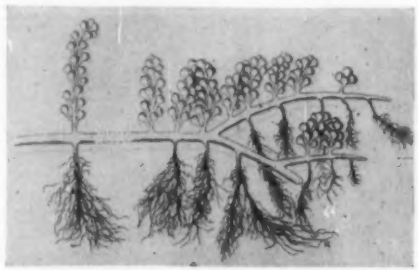

Fig. 3. *Caulerpa racemosa* var. *uvifera*: habit, X 0.4 (after Boergesen, 1907).

Vernacular Name: ar-arusip (Philippines: Luzon, Ilocos Prov.)

Literature: **132**, pl. 230 (sub nom. *Fucus uvifer*). **138**, 362. **36**, 129.

Distribution: Red Sea. Ceylon. Indonesia: Celebes, Buru, Rotti Is. Philippines: Luzon (Ilocos and Cagayan

Prov.). Japan, Australia. Atlantic coast of America. West Indies.

Use: The variety is eaten raw as a salad.

Caulerpa serrulata (Forskal) J. Agardh

Vernacular name: galgalacgac (Philippines: Luzon, Ilocos Prov.)

Literature: **43**, 188 (sub nom. *Fucus serrulatus*). **3**, 446 (sub nom. *Caulerpa freycinetii*). **5**, 17, **88**, 24, 63. **36**, 129. **31**, 498.

Distribution: Singapore. Philippines: Luzon (Ilocos Prov.). Indonesia: Tikus I. (W. coast of Sumatra), E. coast of Borneo, Celebes, Timor, Moluccas; New Guinea. In all tropical seas.

Use: The species is eaten in Singapore.

Caulerpa sertularioides (Gmelin) Howe

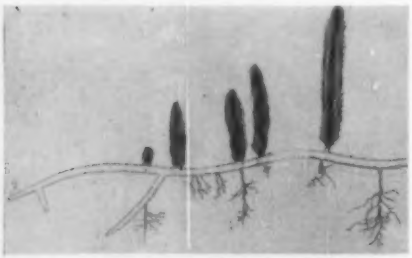

Fig. 4. *Caulerpa sertularioides* habit, X 0.5 (after Boergesen, 1907).

Vernacular name: salsalmagni (Philippines: Luzon, Ilocos Province)

Literature: **47**, 154 pl. 15, f. 4 (sub nom. *Fucus sertularioides*). **68**, 576. **36**, 129.

Distribution: Indonesia. Philippines In all tropical seas.

Use: The species is eaten raw as a salad.

Chaetomorpha Kuetzing
Cladophorales, Cladophoraceae

The plants are composed of unbranched filaments, which sometimes fasten themselves by means of more or less branched rhizoids; in other species, however, they are not attached at all, the filaments being twisted together forming intricate clumps, resting on stones or other algae. The genus is found both in the sea and in brackish water all over the world. Mainly attached to rocks in the littoral zone (ultra-littoral belt).

Note: The arrangement of this genus in the order Cladophorales is in accordance with Fritsch **44**. More frequently it is placed in the order Siphonocladiales.

Chaetomorpha antennina (Bory) Kuetzing

Vernacular names: limu huluilio, limu ili or limu mami (dog's hair).

Literature: **98**, 4 (sub nom. *Conferva antennina*). **73**, 379. **110**, 86.

Distribution: Indonesia. Vietnam. Hawaiian I. Mexico. Ecuador. West Indies. S. Africa. Seems to occur in all tropical seas.

Use: *C. antennina* occurs in Malaysia, but it is not known if it is eaten in this region though this is probably the case. In Hawaii and Maui (Reed **110**) the species is indeed eaten. The vernacular names quoted above for this species are also used for *Cladophora nitida* Kuetz.

Chaetomorpha crassa (C. Agardh) Kuetzing

Vernacular names: kauat-kauat (Philippines: Luzon Union Prov.) ririppus (Philippines: Luzon, Ilocos Prov.)

Literature: **4**, 99 (sub nom. *Conferva crassa*). **73**, 379. **117**, 309. **145**, 21. **36**, 129. **31**, 518.

Distribution: Red Sea. Indonesia: Bay of Djakarta (I. of Leiden). Philippines. Japan. Australia.

Use: The plants are commonly prepared so as to make a gelatine-like sweet meat from them. Sometimes the species is eaten as salad.

Chaetomorpha javanica Kuetzing

Vernacular names: lumut laut, sajur lompan, rumut kehur (Malay). haair der nymphen (old Dutch); hauty, tsjenthi (Chinese). All names used in the Isle of Ambon.

Literature: **73**, 376. **114**, 90, 179-180 (sub nom. *Capillus nympharum*, *Sericum marinum*, *Muscus marinus* and *Muscus capillaris*) (not pl. 40, f.3, this representing *Gelidium amansii*). **88**, 42. **60**, 323. **90**, 53.

Distribution: Indonesia: Java, Ambon. West Indies.

Use: According to Rumphius the Chinese at Ambon collect these weeds in the months of August and September (dry monsoon). After being soaked a night in fresh water they are dried in the sun. The dried weeds are boiled and eaten with bacon.

Codium Stackhouse
Siphonales, Codiaceae

The thallus of the species of this widely distributed genus is spongy. The erect, r i c h l y dichotomously branched threads of the plants are anchored by a small cushion-like disc or by tufts of rhizoids on coral reefs or on exposed rocks in the surf (littoral region).

Note: The method of preserving *Codium* species for food in Japan is to put them in salt (Okamura **102**).

Codium muelleri Kuetzing

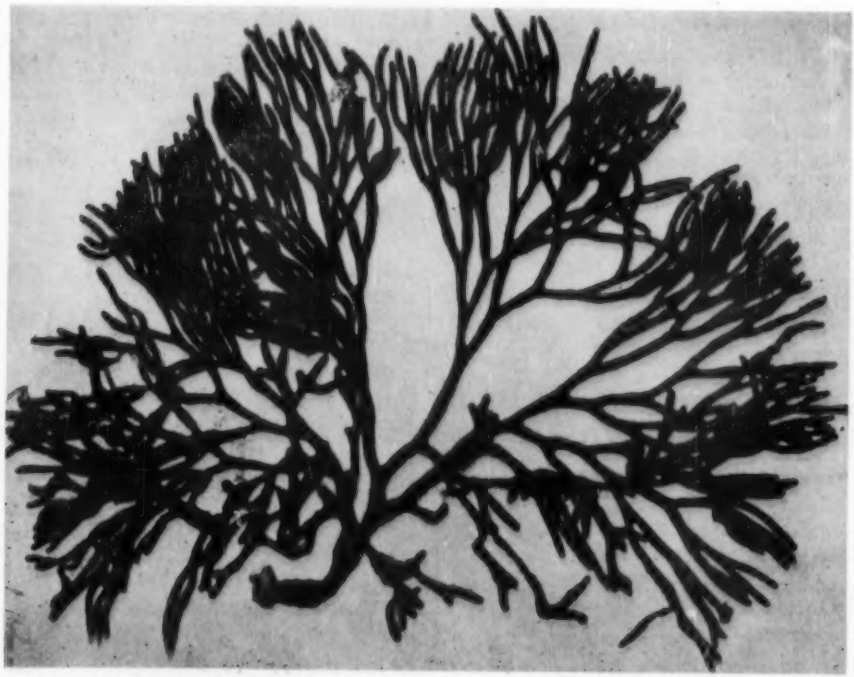

Fig. 5. *Codium muelleri*: habit, X 1 (after Lucas, 1936).

Vernacular names: popoklo (Philippines: Luzon, Ilocos Prov.); siling siling (Philippines: I. of Leyte, Cebu, Bokol, Visayan dialect); limu aalaula, limu wawaeioe, limu wawaimoa (Hawaiian Islands).

Literature: **72**, 34, t. 95, f. 2. **110**, 63. **87**, 477. **36**, 130. **94**, 47.

Distribution: Hawaiian Islands. Australia, Tasmania, New Zealand.

Use: In the Hawaiian Islands the species is eaten raw, usually with tomatoes, after being thoroughly washed in fresh water. It is never cooked or blanched, for it becomes soft and disintegrates quickly with heat. Moreover, Miller **94** states: "The ascorbic acid content of a specimen which had been kept in sea water in a refrigerator for two days after gathering was found to be low, only 5 milligrams of ascorbic acid per 100 grams."

Codium tenue Kuetzing

Vernacular names: pupu-lo (Philippines: Luzon, Union and Ilocos Prov.).

Literature: **72**, 33, t. 95. **117**, 309. **145**, 21. **36**, 129. **31**, 617.

Distribution: Indian Ocean, incl. Red Sea. Indonesia: Sulu Archipelago. Philippines. Cape of Good Hope.

Use: Eaten raw as a salad in the Philippines.

Codium tomentosum (Hudson) Stackhouse

Vernacular names: susu lopek (E. Lombok); laur-laur (Celebes); limu aalaula (Hawaiian Islands). The latter also used for *C. adhaerens* (Cabr.) Ag.

Literature: **71**, 584 (sub nom. *Fucus tomentosus*). **123**, 16. **88**, 47. **15**, 260. **110**, 86. **64**, 319. **128**. **63**, 33. **31**, 617.

Distribution: Widely distributed in all oceans except the polar regions.

Use: The species is sold in the markets of Makassar and is used as food in several parts of Malaysia. It is eaten raw as a salad.

Okamura **102** states that species of *Codium*, e.g. *C. tomentosum* are copied as designs in fine arts. One of the plants is neatly straightened out on paper in a flabellate form, then copied and used as a pattern on porcelain, fabric, wall paper, etc.

Enteromorpha Link.
Ulotrichales, Ulvaceae

Thallus of the plants tubular, simple or with more or less numerous branches. The species occur in the upper parts of the littoral zone near the shore in quiet waters, attached to small stones and rocks by means of rhizoids. *Enteromorpha* species are capable of enduring a wide range of salinity, therefore often occurring in brackish water or estuaries. The three species mentioned below are very closely allied (Weber-Van Bosse **140**).

Note: An extensive study of the food value of the Hawaiian *Enteromorpha* species, known under the same vernacular name, was made by Miller **92**. The edible species are known as limu ele-ele or limu pipilani.

A chemical analysis of an *Enteromorpha* species gave the following result (p. 19):

Water	90.34 %
Protein (N x 6.25)	2.82 %
Fat (Ether extract)	0.0485%
Ash	1.59 %
Calcium	0.17 %
Phosphorous	0.0336%

As to the vitamin contents, Miller stated (p. 24): "Limu ele-ele is a fairly good source of vitamin A and a less good source of vitamin B. The value of limu in diet is its flavour and its tendency to prevent constipation. Limu ele-ele has no antiscorbutic value."

Species of *Enteromorpha* are food for many fishes, e.g. *Chanos chanos* (Bandeng).

The genus occurs in Ceylon but the species is unidentified as yet.

Enteromorpha compressa (L.) Greville

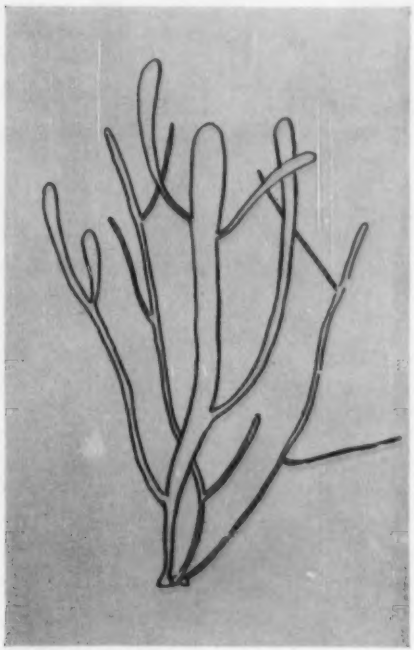

Fig. 6. *Enteromorpha compressa*: habit, X 3 (after Lucas, 1936).

Literature: **83**, 1163 (sub nom. *Ulva compressa*). **50**, 180, t. 18. **130**, 112. **31**, 928.

Distribution: Cosmopolitan. Malay Peninsula. Indonesia: Sumatra (Benkoelen), Java (Bantam).

Use: Eaten in the Philippines and in the Malay Peninsula. From an analysis given by Tressler **130**, 112 it seems that more than half of the weight of an air dried plant is digestible food.

Enteromorpha intestinalis (L.) Link

Vernacular names: lumot (Philippines: Luzon, Union and Ilocos Prov.). ruprupu (Philippines: Luzon, Ilocos Prov.); limu ele-ele, limu pipilani (Hawaiian I.).

Literature: **82**, 432 (sub nom. *Ulva intestinalis*). **81**, 5. **117**, 309. **110**, 86. **87**, 476. **145**, 21. **36**, 129-130. **31**, 928. **135**, 100.

Distribution: India: Pamban area. Malay Peninsula. Indonesia: Java (Semarang). Philippines. Hawaiian Islands. Cosmopolitan, but as far as I know not yet recorded from the Red Sea or the China Sea.

Use: In the Philippines the species is eaten raw as a salad. According to Hooper **67** the Chinese import it dried into the Malay Peninsula. It is eaten by the Japanese as a supplementary article of diet with boiled rice only after being sun dried (Okamura **102**). According to Velasquez **135**, 100 the species serve as food for the milkfish in the Philippines: "where fish feed on algal growth in the pond other than this green alga and *Chaetomorpha aerea* (Dillw.) Kuetz., they develop an unpleasantly strong fishy

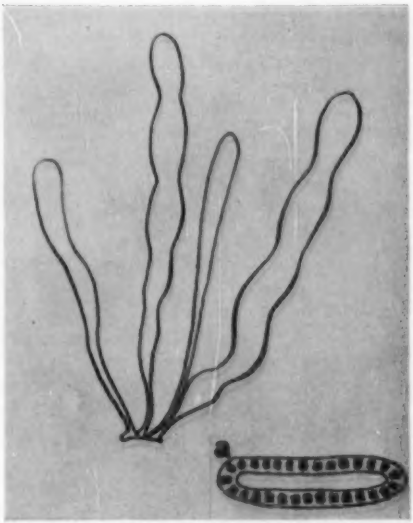

Fig. 7. *Enteromorpha intestinalis*: habit. X 2; a. cross section (after Lucas, 1936).

taste. It would therefore appear that the food reserve in the green algae has a direct bearing on the palatability of the milkfish."

Enteromorpha prolifera var. **tubulosa** (Kuetz.) Reinbold

Vernacular names: limu ele-ele, limu pipilana (Hawaiian I.)

Literature: **9**, 129, t.4, f. 103-104. **72**, 11, pl. 32. **111**, 117. **110**, 86. **31**, 928.

Distribution: Malay Peninsula. Indonesia: Java (Djakarta), Leti I. Hawaiian I. Pacific Ocean: American coast. Atlantic Ocean: European coast.

Use: Only mentioned as eaten on the shores of Malay Peninsula.

Ulva L.
Ulotrichales, Ulvaceae

The flat, broad and membranaceous thallus consists of two layers. It is attached by a small disc to rocks, stones, valves, etc., in the upper part of the littoral zone (ultra- and supra-littoral belt). These seaweeds prefer spots where the water is polluted by organic matter and where supplies of fresh water mingle with seawater.

Ulva lactuca L.

Vernacular names: limu lipalahalaha, limu palcaea (Hawaiian I.).

Literature: **83**, 1163. **110**, 88. **87**, 476. **31**, 1196.

Distribution: Ceylon. India: Pamban area. Malaya. Indonesia: Sulu I., Kei I., Celebes, Lombok, Sumba, Banda, Solor I., Salebabu I. Philippines. Hawaiian I. Cosmopolitan.

Use: Though *Ulva lactuca* is a common plant in the whole of Malaysia it is mentioned only by Burkill. However, this author states that the sea lettuce is eaten widely in the East, in soup, as salad and that it is employed for garnishing. On account of this it is somewhat surprising that no vernacular names are reported from these regions. In Japan (Okamura **102**) it is called "awosa-awosa."

In Singapore the plant is used only for feeding pigs. It may be that it is neglected there as human food because "the sea water is not a little polluted."

Tressler **130**, 112 gave an analysis showing that 50% of carbohydrates are present and 15% of proteins if water be reduced to 19%.

Note: Mr. H. M. Ridley, assistant director of Botanic Gardens, Singapore, kindly advised me that *Ulva lactuca* and *Ulva reticulata* are collected in Singapore. (1958.)

PHAEOPHYTA

Chnoospora J. G. Agardh
Ectocarpales, Encoeliaceae

The members of this small genus of tropical (especially Pacific) algae are characterized by the irregular dichotomously branched thalli bearing numerous tufts of hairs, the forks being closer and closer upwards. The aggregated sporangia are spread over the surface and arise from the hairs.

The relatively tough, more or less compressed, wiry branches are composed of a central and a cortical tissue. The plants are, in a dried state, very dark brown. The tufted plants are attached to stones, rocks, and pieces of dead coral in the littoral region.

Note: Though the under-mentioned species is only once recorded for the region under discussion (Java), Levring **80** it is treated here as it is difficult to distinguish from the nearly related *C. implexa* (Her.) J. Ag., which occurs in many parts of South and East Asia. However, no mention is made about economic particulars of that species in the area under discussion. The remarkable geographical distribution of *C. pacifica* may be an indication that the two species are identical.

In the Hawaiian Islands *Chnoospora implexa* is known by the vernacular names "limu wawahiwaa" and "limu kaupau" (Reed **110**).

Chnoospora pacifica J. G. Agardh

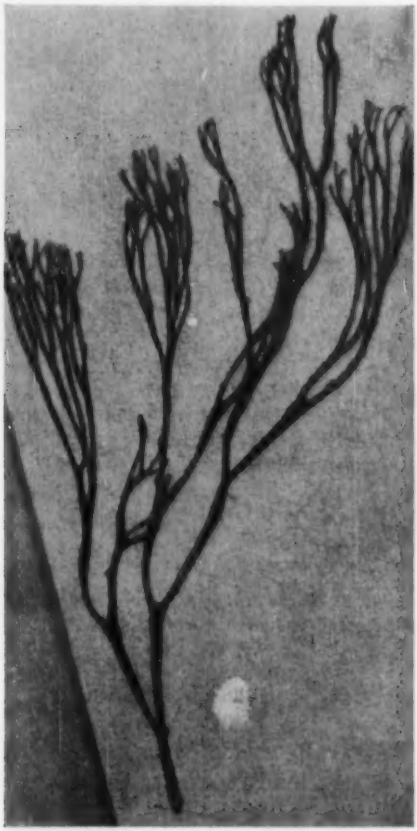

Fig. 8. *Chnoospora pacifica*: habit, X 0.9 (after Dawson, 1954).

Vernacular name: rau ngoai (Indo-China).

Literature: **7**, 7. **8**, 172 (sub nom. *Chnoospora fastigiata* var. *pacifica*). **54**, 137 (sub nom. *Chnoospora fastigiata*). **31**, 530.

Distribution: Indian Ocean: Durban, Ceylon. Indo-China. Indonesia: Java. Pacific Ocean: Japan, Australia, Hawaiian I., coast of Mexico. Atlantic Ocean: West Indies.

Use: The species is eaten raw, like a salad or relish, but nothing is recorded regarding its use in Malaya, the Philippines, and Indonesia.

Hydroclathrus Bory de St. Vincent
Ectocarpales, Encoeliaceae

The thallus of this very peculiar genus is, in the full-grown state, hemispherical and regularly pierced with orbicular holes. These holes gradually dilate more and more, thus forming an open meshwork up to 25 cm. in diameter. The mature specimens, therefore, have the aspect of a sponge loosely attached by the lower surface to the substratum. The young thalli, in the earliest stages, are hollow and not perforated.

Hundreds of these yellowish-olive, netlike expansions are sometimes heaped together by wind and waves in the lagoons of the coral reefs. The color, however, rapidly changes, and the seaweeds become dark brown in a dried state, loosing rigidity at the same time.

Hydroclathrus clathratus (Bory ex C. A. Agardh) Howe

Vernacular name: balbalulang (Philippines: Ilocos Prov.).

Literature: Bory de St. Vincent in ms. sub nom. *Fucus clathratus* (vide **3**, 412 sub nom. *Encoelium clathratum*). **3**, 419 (sub nom. *Hydroclathrus cancellatus*). **15**, 842; ed. 2, **15**, 582; ed. 3, **15**, 262 (sub nom. *Ulva reticulata*). **57**, pl. 98 (sub nom. *Hydroclathrus cancellatus*). **88**, 47 (sub nom. *Encoelium clathratum*). **91**, 40 (sub nom. *Hydroclathrus cancellatus*). **69**, 589. **36**, 129 (sub nom. *Hydroclathrus cancellatus*). **135**, 100.

Distribution: India: Pamban area. Singapore. Indonesia: Borneo, Celebes, Java, Sumbawa, Timor, Tawi-Tawi I., New Guinea. Philippines. Austral-

ia. Seems to occur in all tropical seas.

Use: Collado **36**, 129 states that the species is eaten raw as a salad in the Philippines (Ilocos and Cagyan Prov.). However, Von Martens **88**, 47 did not believe that it was used by the natives there. Setchell **118**, 113 reports that Miss Tilden collected specimens of *Hydroclathrus clathratus* in the Hawaiian Islands under the native name "poha," adding that: "It is eaten raw by the natives," thus establishing the fact of the edibility of this species. According to Velasquez **135**, 100 it is used as a fertilizer in the Philippines.

Dictyota Lamouroux
Dictyotales, Dictyotaceae

The flattened thallus of these membranaceous plants arises from a stipose base. The branching exhibits practically a perfect dichotomy, the lobes being fan-shaped above with entire or dentate edges. The thallus is composed of three layers, a central one of large, colorless cells and an upper and lower cortical one of small cells with chromatophores. The male and female sex organs are borne on separate plants. Both kinds of gametes are liberated in a single hour at about daybreak. Asexual plants, showing a similar morphological appearance as the sexual ones, reproduce by means of tetraspores. All the reproductive cells derive from the superficial cell layer.

When exposed to the sun, the olive-brown color becomes verdigris green.

The plants occur on a rocky substratum in the semi-littoral belt and especially in the sublittoral region.

Dictyota apiculata J. G. Agardh

Vernacular name: unknown.

Literature: **9**, 67. **105**, 12. **31**, 805.

Distribution: Malay Peninsula. Indonesia: Celebes. Australia, Tasmania.

Use: The plants are eaten where the surf throws them up on the beach, but I do not know in what way. In the Hawaiian Islands several other species of the genus *Dictyota* are eaten, among others, the widespread *Dictyota dichotoma*. Some of the species are bitter (Reed **110**, 86).

Padina Adanson
Dictyotales, Dictyotaceae

The thallus of the plant is flat, leafy, fan-shaped, fringed with articulated hairs, and marked at regular distances with concentric lines. The fronds are entire or sometimes split into sections. The tissue is differentiated into two kinds, a single upper and lower surface layer of assimilating cells, and a central one consisting of two or more layers of parallel-epipedal cells. Male and female gametangia occur on the same plant, in concentric zones between the fringed bands. The tetraspores are developed on separate plants of the same appearance and are scattered along the margins of the zones.

The property of the fronds of reflecting prismatic colors while growing under water, together with the fan-like shape, have given the seaweeds the popular name of "peacock's tail."

The algae grow on a somewhat sandy bottom, in lagoons, etc., attached to little coral pieces, shells and stones by organs which are densely coated with woolly hairs. They occur in the lower part of the littoral (Zaneveld's semi-littoral belt **151**, 466) and in the highest part of the sublittoral region.

Note: As it is not certain to what species Blanco's description applies, the most widespread one in the Philippines is mentioned below. *Padina distromatica* has only been recorded once, from Panay Island (Howe **70**, 169).

Padina australis Hauck

Vernacular name: agar-agar daun besar (Indonesia: Klapa I.)

Literature: **61**, 144. **15**, 842; ed. 2, **15**, 581; ed. 3, **15**, 261 (sub. nom. *Ulva umbilicalis*). **88**, 47 (sub nom. *Zonaria*

gymnospora). **91**, 40. **70**, 170. **135**, 100.

Distribution: Red Sea. India: Pamban area. Indonesia: Sumatra, Java, Celebes, Lombok, Sumbawa, Buru, Amboina, Djedan I. China Sea. Philippines: Luzon, Panay I. Australia.

Use: The species is sometimes eaten as a salad, but frequently it is collected for preparing a gelatine-like sweetmeat. Velasquez **135**, 100 states that *Padina* species are used as a fertilizer in the Philippines. The Director of Fisheries in Ceylon communicated to me that *P. commersonii* Bory and *P. tetrastromatica* Hauck both are used in Ceylon.

Sargassum C. A. Agardh
Fucales, Sargassaceae

The plants belonging to this genus have the appearance of land plants showing a differentiation into "roots," "stems," and "leaves." The vertical dichotomously branched axis is attached to the substratum by a distinct, often massive, lobed holdfast (the "roots"). The axis has a short stipe-like portion (the "stem"), and bears in the upper parts the repeatedly alternate branches on all sides with broad to filiform, entire or serrate, leaflike organs, showing a mid-rib. Moreover, it is often provided with stalked air-bladders (vesicles) and more or less forked, cylindrical receptacles, developing in the axis of the so-called "leaves."

The stipes are attached to rocks, dead coral pieces, etc., in the sub-littoral region, sometimes forming a dense zone around a coral island being settled upon the abrasion lay of the reef. On the other hand, masses of *Sargassum* plants are often floating in the sea, having been torn off the shore by storms and carried to the open water by currents. The plants regenerate from broken thalli.

Note: The ash of burnt *Sargassum* species contains a large quantity of potash and carbonate of soda. Therefore, the plants were cultivated in the coastal regions of some countries and the ash sold under the name of "kelp" (Zaneveld **154**). Iodine is another valuable constituent found in the tissues, especially in those weeds collected in the open sea. Iodine industries exist in Japan and the United States.

A chemical analysis of a *Sargassum* species carried out by Collado **36**, 134 in the Experiment Station Food Laboratory of the College of Agriculture gave the following results:

Moisture	33.44%
Protein	5.01%
Carbohydrates	30.24%
Fat (ether extract)	1.29%
Crude Fiber	5.13%
Ash	24.89%
Iodine	0.39%

The species used, probably *Sargassum siliquosum*, is known in Ilocos Province (Philippines) as "aragan."

Another analysis of an Indian *Sargassum* species (Chidambaram and Unny **34**) gave the following results:

Moisture (air dry samples)	11.72%
Loss on ignition	61.63%
Insolubles	0.17%
Solubles	26.48%
Nitrogen	1.02%
Potash	5.99%
Phosphoric acid	0.21%

Sargassum tennerimum and *S. wightii* of Travancore-Cochin State were analyzed (Pillai and Varier **106**) for their iodine content, which amounted to 0.016%; the alginic acid content respectively 34.6% and 29.8% and mannitol, 9.4% and 7.3%.

Dried *Sargassum*, *Turbinaria* and *Gracilaria* species are used as manure in coconut plantations in the Madras Presidency. The material is placed in a pit around the palm three to four feet from the base and then covered with earth.

Sargassum is a very large genus of world-wide distribution. The Malays call them collectively dandigum (Burkill **31**, 66). Mrs. Weber-Van Bosse **140**,

489 mentions 58 different species for Indonesia alone! It is impossible, therefore, to give the exact names of the species insufficiently described by the older authors like Rumphius and Blanco.

The *Sargassum* species cited in Blanco's "Flora Filipinas" **15**, 839 sub nom. *Fucus denticulatus* sp. nov; ed. 2, **15**, 579 and ed. 3, **15**, 259 sub nom. *Fucus natans* is, according to Merrill **91**, 46 "apparently the one common at certain seasons in Manila Bay. Its true position within the genus *Sargassum* has not yet been determined." Von Martens **88**, 45 adds to Blanco's species: "Verschiedene Arten von *Sargassum*." The Philippine plants of this species are eaten by the natives. However, neither Blanco nor Von Martens was aware in what way the food was prepared. The *Sargassum* species mentioned by Vorderman **136**, 406 and by Hofstede **64**, 319 under the vernacular name "bebojot," is eaten in East Lombok. Cf. Tondo quoted by Chapman **33**, 186. *S. ilicifolium* (Turn.) J. Ag. is used in Ceylon. According to Hooper **67**, 28 the Chinese pharmacies in the Straits Settlements stock a dried *Sargassum* species. The exact use is not known, but it is a recognized Chinese drug. Velasquez **135**, 100 states that *Sargassum* species are used as a fertilizer in the Philippines.

Sargassum aquifolium (Turner) C. A. Agardh

Vernacular names: arien wari (Amboina); latak (Malay).

Literature: **132**, 112, pl. 50 (sub nom. *Fucus aquifolius*). **3**, 12. **114**, 186 (sub nom. *Agarum funiculare sive foliatum* p.p.). **88**, 43 (sub nom. *Carpacanthus herbaceus*). **60**, 323 (sub nom. *Sargassum* sp.). **90**, 55. **63**, 33. **31**, 1966.

Distribution: Red Sea. Indian Ocean: Nicobar I. Indonesia: Sunda Str., Java, S. Flores, Timor, Amboina, Aru I. Pacific: Australia, New Ireland, Admiralty I.

Use: According to Rumphius **114**, 186 the tops of the weeds are eaten raw or cooked with coconut milk.

Sargassum granuliferum C. A. Agardh

Vernacular names: arien wari (Amboina); latak (Malay).

Literature: **3**, 31. **114**, 186 (sub nom. *Agarum funiculare sive foliatum* p.p.). **88**, 43. **90**, 55. **63**, 33. **31**, 1966.

Distribution: Malay Peninsula: Singapore. Indonesia: Sumatra, Banka, Sunda Str., Java, Celebes, Timor, Amboina, New Guinea. China Sea. Japan. Australia. Tahiti I.

Use: In Amboina the upper parts of the plants are eaten raw or cooked with either coconut milk or a little vinegar.

Sargassum polycystum C. A. Agardh

Vernacular names: agar-agar kupan (Moluccas); arien harulu, arien malona (Amboina).

Literature: **4**, 304. **32**, 239 (sub nom. *Fucus natans*). **114**, 185 (sub nom. *Acetabulum marinum, sive Agarum primum*). **62**, 185 (sub nom. *Sargassum amboinicum*). **60**, 181 (sub nom. *Sargassum myriocystum*), **88**, 43 (sub nom. *Chauvinia macrophysa*). **90**, 55. **63**, 33.

Distribution: Indian Ocean: Mauritius. Malay Peninsula: Singapore. Indonesia: Sumatra, Sunda Str., Java, Celebes, Bali, Sumbawa, Timor, Amboina, New Guinea. Japan. Philippines: Negros I. Australia.

Use: According to Rumphius **114**, 185 the plants are eaten raw with lemon juice after being washed. Sometimes the seaweeds are first cooked with coconut milk. The natives in Amboina preserve the seaweeds smoke-dried.

Sargassum siliquosum J. G. Agardh

Vernacular name: aragan (Philippines: Ilocos Prov.).

Literature: **8**, 316. **117**, 309. **145**, 21. **36**, 129. **31**, 1966.

Distribution: Malay Peninsula: Singapore. Indonesia: Java, Celebes, Kei I., Aru I., New Guinea. China Sea. Philippines: Luzon I., Negros I. Japan. Australia. New Ireland.

Use: In the Philippines the seaweeds are eaten either fresh as a salad or cooked as a vegetable.

Turbinaria Lamouroux
Fucales, Sargassaceae

The plants of this little genus are attached to the substratum by short-branched holdfasts, sending up one or a few simple or branched axes. The stiff, cylindrical, main axis or stipe bears the leaf-like organs. These have the appearance of a triangular shield or disc with a serrate or nearly entire margin, tapering downward usually in a pyramidal fashion to the petiole. The air-bladders, when present, are immersed in the leaf-like organs near the end. The receptacles grow into dense clusters from the base of the petioles.

Turbinaria spp. occur in the sublittoral region of the warm waters of the tropics and subtropics, growing on rocks and pieces of dead coral.

Note: Velasquez **135** states that species belonging to the genus *Turbinaria* are used as a fertilizer in the Philippines. Tondo **128**, quoted by Chapman **33**, 187 says that *Turbinaria* species are eaten in the Riouw Archipelago. According to Chidambaram and Unny **34**, *Turbinaria* species are also used as manure in the Madras Presidency. A chemical analysis carried out by these authors gave these results:

Moisture (air dry sample)	6.13%
Loss on ignition	63.07%
Insolubles	0.50%
Solubles	30.30%
Nitrogen	0.96%
Potash	9.11%
Phosphoric Acid	0.27%

The authors state that washed and dried species of *Turbinaria*, *Sargassum* and *Gracilaria* are applied as manure in coconut plantations in pits around the palm, three to four feet from the palm, and covered with earth.

Turbinaria ornata (Turner) J. G. Agardh

Fig. 9. *Turbinaria ornata*: upper part of plant. X 1.5 (after Dawson, 1954).

Vernacular names: agar-agar lesong, sajur lompan (Malaysia); arien essong, arien hoar, arien makina (Amboina).

Literature: **132**, 50, pl. 24 f. (sub nom. *Fucus turbinatus* var. *ornatus*). **8**, 266. **114**, 186 (sub nom. *Acetabulum marinum*, altera seu *infundibiliformis* species). **62**, 185 (sub nom. *Sargassum turbinatum*). **15**, 842; ed. 2, **15**, 581; ed. 3, **15**, 260. **60**, 181. **88**, 43. **90**, 55. **63**, 33. **31**, 2193.

Distribution: Ceylon. Malay Peninsula: Singapore. Indonesia: Java, Postillon I., Celebes, Madura, Sumbawa, Flores, Banda-Neira, Amboina, Buton Str. Philippines: Niuafoo I. In all tropical and temperate seas from Cape

of Good Hope, New Zealand and Chile in the south to the China seas in the north.

Use: In the Moluccas the seaweeds are most frequently eaten raw with lemon juice but sometimes are cooked with coconut milk. Burkill **31**, 2193 mentions that the seaweeds are made into a pickle in eastern Malaysia.

According to Setchell **118**, 100 the Kawaihae fishermen (Hawaiian Islands) report: "that limu-kala (the vernacular name applied equally to species of *Turbinaria* and *Sargassum*) is used for two purposes: (1) food, and (2) for atonement, religious, not moral. The one who has sinned gets all persons concerned together, makes prayer, and then throws the limu from him."

I know of no use of seaweeds in ceremonies of personal purification in Malaysia.

Turbinaria conoides (J. G. Agardh) Kuetzing

Vernacular name: labi labi (Celebes).

Literature: **8**, 267 (sub nom. *Turbinaria vulgaris* var. *conoides*). **72**, 24, pl. 66. **114**, 186 (sub nom. *Acetabulum marinum*, species quae in Maccassarensium crescit litoribus). **60**, 181 (sub nom. *Turbinaria vulgaris* var. *conoides*). **88**, 43 (sub nom. *Chauvinia macrophya?*). **90**, 56. **63**, 33. **31**, 2193.

Distribution: Red Sea. Ceylon. India: Malabar Coast, Pamban area. Malay Peninsula: Singapore: Indonesia: Sumatra, Java, Postillon I., Celebes, Talaud I., Flores, Amboina, Aru I., New Guinea. China Sea. Philippines: Panay I. Torres Str. W. Australia.

Use: According to Rumphius **114**, 186 the seaweeds belonging to this species are eaten raw by the native chiefs (Radja's) as a salad with a little vinegar. They are pleasant to taste. Burkill **31**, 2193 reports that these seaweeds are made into a pickle in eastern Malaysia.

Govindachari and Rajagopalan **48** state that all of the Indian brown seaweeds so far subjected to preliminary examination, i. e. *Turbinaria conoides, Padina* sp. and *Sargassum* sp., afforded a sterol which is most probably identical with fucosterol, a component of all Phaeophyta in colder waters. However, "the low yields in which fucosterol and other algal sterols have hitherto been obtained will, perhaps, militate against their use as profitable, natural hormone precursors."

RHODOPHYTA

Porphyra C. A. Agardh
Bangiales, Porphyridiaceae

The dull purplish thallus of the plants belonging to this genus is flat and thin, foliaceous, one or two cells thick. The plants are very short-stalked and attached by a very small holdfast, expanding above into a soft slippery blade with an entire or lobed margin.

The species of this genus grow in the littoral zone on stones and rocky parts and show marked resistance against desiccation.

The different species of *Porphyra* furnish a plentiful supply of food to people in quite distant regions of the earth. In Scotland, Wales, and Ireland *Porphyra* species are used as laverbread. It is usually served with bacon for breakfast, made into small flat cakes, and fried crisp in the bacon fat or heated with butter, lemon juice, and pepper and served with roast mutton (Newton **100**). According to Printz **109a** *P. umbilicalis* (L.) J. G. Ag. is used in the same way.

It is a well known fact that *P. tenera* Kjellm. has been cultivated on a large scale in several parts of Japan, notably in Tokyo Bay, from a very early period. The Japanese name for this seaweed is "amanori." H. M. Smith **120** gave a full description of the aquiculture of *P. tenera* around Tokyo Bay of which the following may be cited here: "In Octo-

ber or November, at low tide, men go out in small boats with bundles of bamboo prepared for the purpose. In order to make holes, up to 10 or 15 ft. deep at high tide, conical wooden boxes or frames are pushed down into the muddy bottom. Then the bundles of bamboo are "planted" or set out, in these holes."

It is known that the spores of *Porphyra* float in the water before dropping down and becoming attached to some object. Here they attach themselves to the twigs of the bamboo bushes and develop so rapidly that by January they have grown into full-sized plants. Now it is the turn of the women and girls, who finish the business of harvesting the crop.

The fresh red fronds of amanori picked from the twigs are thrown into tubs of fresh water and stirred with long sticks in order to remove the sand and other foreign substances. The plants are then sorted, chopped with sharp knives into fine particles, and spread out in sheets of a uniform size on bamboo mats placed on inclined frames in the open air. In a short time the amanori sheets are dry. To get them ready for the market they are stripped from the mats, pressed, and then made into bundles of ten sheets each, the dimensions being approximately ten by fourteen inches. The sheets have the appearance of dark brown mottled paper with a glossy surface, and in this form they are sold to the consumer under the name of asakusanori.

Before being eaten it is crisped over a fire, which changes the color to green; then it is rubbed between the hands, and the small pieces are dropped into soups or sauces to give a pleasant flavor. Nowadays it is often preserved in tins after having been boiled with soy bean sauce. Yendo **148** has given the recipe for making "sushi," one of the most common seaweed foods in Japan. First, cold boiled rice is spread over a sheet of asakusanori; on the rice are laid pieces of meat or fish. The entire sheet or layer is then rolled, like an American jelly roll, and cut into slices.

Miller **93** states that all seaweeds used by the Japanese in Hawaii are imported in the dry state from Japan. The purplish-red nori is the one most commonly used in Hawaii. According to Velasquez **135** an unnamed species of *Porphyra* has been cultivated in the Philippines in North Luzon. The growth and processing here are similar to methods employed in Japan.

Porphyra atropurpurea (Olivi) De Toni

Vernacular names: limu luau, limu lipahee (Hawaiian I., Kauai, Hawaii); gamet (Philippines: Ilocos Prov.).

Literature: **103a**, 153, t. 1-3. **129**, 17. **126a**, 100 (sub nom. *Porphyra leucosticta*). **110**, 88. **93**, 20. **127**, 199. **94**, 47.

Distribution: Indonesia. Philippines. Hawaiian I. Nearly cosmopolitan.

Use: Limu luau is considered a great delicacy in the few localities where it occurs in Hawaii. It is found on bold exposed rocks constantly dashed by waves; so it is difficult and dangerous to collect it, especially as it is extremely slippery and has to be scraped forcibly from the rocks in small bunches while the collector clings to his support and avoids the heavy waves.

After being washed in fresh water the seaweed is salted, tied closely in layers of "ti" leaves, and kept in a shady place. To preserve it for a long period of time the pounded seaweed is salted and stored in calabashes. Sometimes opihi, a kind of limpet, is put in with the limu, salted, and placed in bottles or jars. It keeps many weeks and is used as needed.

When used for medical purposes, limu luau is pounded to a pulp with salt, and the juice is used to moisten bandages on cuts or bruises.

According to Miller **93**, 21 the dried *Porphyra* material bought on the Hawai-

ian markets is shipped in from Japan in bundles of flat sheets, 7½ by 8½ inches, and as thin and flexible as tissue paper. These sheets are made by chopping the fronds of fresh algae that are spread upon mats to dry. The sheets are then made into bundles for the market. Nori is used to garnish sushi, salads, noodles, raw fish, and eggs. It is used in the preparation of maki-sushi by wrapping it around a roll of rice, the center of which is filled with thin strips of fried eggs, roasted eel, green vegetables, mushrooms, and the like.

The dried product called gamet is a species of *Porphyra* used by the Filipinos in Hawaii (Miller **94**, 47). The Filipino product is composed of pieces of the seaweed pressed into flat round cakes about seven inches in diameter. Gamet may be served in several ways. It is added to hot soups containing vegetables, fish, shrimp, or chicken. It may be cut into small pieces or strips, softened in a small amount of water, and served with salad vegetables, especially sliced or mashed tomatoes. It is sometimes fried dry and crisp in a very small amount of fat and served with rice or vegetables.

Acanthophora Lamouroux
Ceramiales, Chondrieae

The plants are erect and bushy, with a base of fibrous holdfast strands. They are up to two dm. high; the color is dull grayish-purple. The branches are long, cylindrical, and stiff, bearing short spur-branchlets, especially developed on the smooth main axes. These spur-branchlets are rather crowded with short spines, spirally disposed.

The seaweeds occur in shallow water, in lagoons, on rocks and dead pieces of corals near the low-tide line (semi-littoral Zaneveld **151**).

Acanthophora spicifera var. **orientalis** J. G. Agardh

Fig. 10. *Acanthophora spicifera*: a branch, X 5 (after Dawson, 1954).

Vernacular names: a b u-a b u (Kangean I.); bulong tombong bideng (E. Lombok); culot (Philippines: Luzon, Ilocos Prov.).

Literature: **133**, 44 (sub nom. *Fucus spiciferus*). **8**, 820 (sub nom. *Acanthophora orientalis*). **16**, 201. **36**, 129 (sub nom. *Acanthophora orientalis*). **128**. **63**, 35. **31**, 25.

Distribution: Indian Ocean: Seychelles I., Tsjagoo I. Malay Peninsula. Indonesia: Kangean I., Lombok. Philippines: Luzon. Marianas I.

Use: At Kangean Island the seaweeds are first immersed in hot water then eaten with lombok (red pepper) or kelor-sauce (prepared from the fruits of *Morynga polygona* DC.).

Agardhiella Schmitz
Gigartinales, Solieriaceae

The thallus of the bushy growing plants is cylindrical; a number of these thalli arise from the same discoid holdfast. The plants are one to three times oppositely or irregularly branched. In the mature thallus the central part (medulla) consists of a mass of loose threads, which is surrounded by a cortex of colored cells.

Agardhiella species grow in the sublittoral region on a rocky bottom to a depth of 55 m.

Note: The name of the species collected in Malaysia has not been mentioned. Most probably it will be *Agardhiella tenera* (J. G. Agardh) Schmitz.

Agardhiella species

Vernacular name: gulaman (Philippines: Luzon).

Literature: **116**, 435. **15**, 839; ed. 2, **15**, 580; ed. 3, **15**, 260. **117**, 309. **145**, 21. **36**, 129.

Distribution: Philippines. According to Wester **145**, 21 the species is common in Manila Bay.

Use: The species is probably the most generally used one in Manila. The algae are brought into the market during the rainy season by fishermen. Gulaman is a very popular gelatin-like sweetmeat among the Filipinos. It is prepared by boiling the seaweeds with sugar and various spices.

Bostrychia Montagne
Ceramiales, Rhodomelaceae

The filiform, cartilaginous plants are pinnately branched. Towards the apex these branches are usually hook-pointed. The articulated tubular main axis is surrounded by one or more concentric rows of colored cells. The sporangia are located in special siliquose branchlets. The color of the plants is dull-purplish.

The species belonging to this genus are characteristic inhabitants on the breathing roots of the mangrove trees occurring in the lagoons along the seashore.

Bostrychia radicans (Montagne) Montagne

See Figure 11.

Vernacular name: Unknown.

Literature: **96**, 199, pl. 5, f. 3 (sub nom. *Rhodomela radicans*). **99**, 286. **109**, 744.

Distribution: Burma: mouth of Salween River. Indonesia: Java (north coast), Dammer I. Pacific Ocean: Colombia, Ecuador. Atlantic Ocean: Guiana, W. Africa.

Use: This species is eaten in Burma either raw or boiled. Nothing is known about its use in Indonesia and other parts of South and East Asia.

Caloglossa (Harvey) J. G. Agardh
Ceramiales, Delesseriaceae

The thallus of the plants is flat and dichotomously branched with a pronounced midrib. The secondary branches arise from this midrib. The tetrasporangia are distributed near the tips of the fronds in parallel transverse lines. The cystocarps are on the upper branches on the underside of the midribs. The male plants are smaller than the females. The color is violet.

The seaweeds are attached to the breathing roots of the mangrove trees or to the rocks by means of holdfasts creeping beneath the dichotomies. They are distributed in the upper part of the littoral region (Zaneveld's ultra and supralittoral belt **151**) and even above that level where the seaweeds are wetted by the spray.

Caloglossa adnata (Zanardini) De Toni

Vernacular name: Unknown.

Literature: **149**, 141, pl. 5b, f. 1-3 (sub nom. *Delesseria adnata*). **129**, 730. **109**, 744.

Distribution: India: Pamban area. Burma: mouth of Salween River. Indonesia: Borneo (Sarawak).

Use: It is eaten raw or boiled like the other members of the Bostrychietum association.

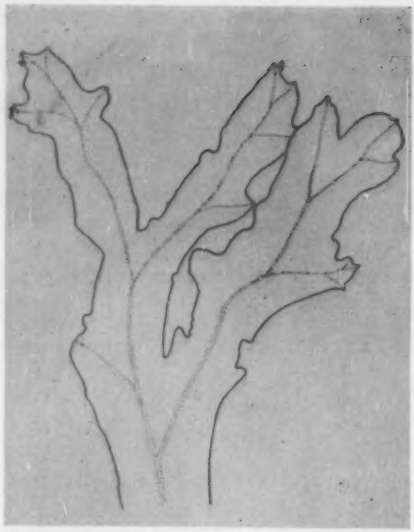

Fig. 12. *Caloglossa adnata*: part of plant, X 3. (after Dawson, 1954).

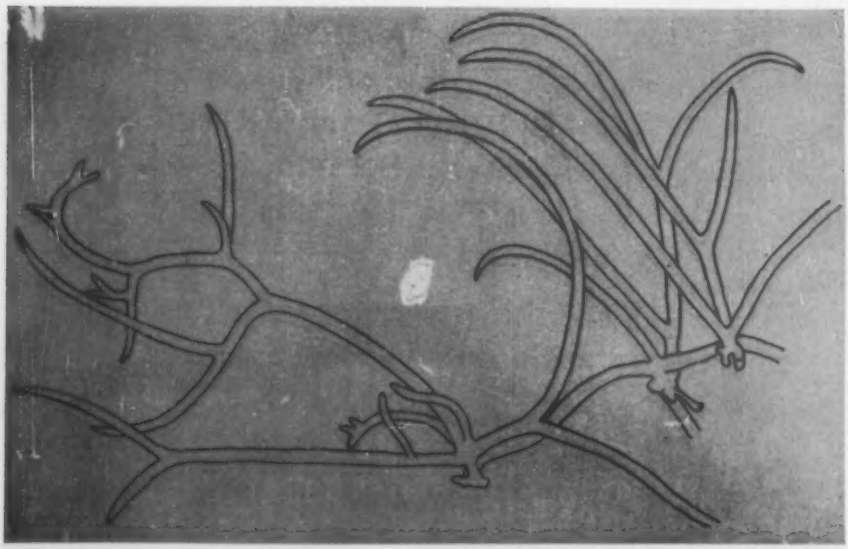

Fig. 11. *Bostrychia radicans*: habit of plant extracted from a mat, X 20 (after Dawson, 1954).

Caloglossa leprieurii (Montagne) J. G. Agardh

Vernacular name: Unknown.

Literature: **96**, 196 (sub nom. *Delesseria leprieurii*). **9**, 499. **109**, 744.

Distribution: Ceylon. Burma. Indonesia: Solor I. Pacific Ocean: Japan, Australia, New Zealand, Colombia, Ecuador. Atlantic Ocean: New York to Florida, Bermuda, Bahamas, West Indies, Europe, Africa.

Use: In Burma the species is collected by the fishermen and brought into the market together with the other members of the Bostrychietum association. The seaweeds are eaten either raw or boiled.

Catenella Greville

Gigartinales, Rhabdoniaceae

The thallus of this small genus is cylindrical or flattened, radially or bilaterally bronched, up to five cm. high, dark violet. The main axis and the branches are composed of compressed joints. Diverse species of the genus are characteristic components of the algal flora found on the breathing roots of the mangrove trees, to which they are attached by haptera. These holdfasts are characteristic for the species. Miss Post **108**, 69 showed that closely related species *Catenella impudica* and C. *nipae* are easy to distinguish by these holdfasts. In the former species the haptera are independent organs developed at the constriction of the joints, whereas in the latter species they are the end of the joints.

Most of the species are widely distributed in the upper littoral belt, especially on muddy rocks in salt marshes, and the seaweeds flourish where they are only occasionally wetted by ocean spray.

Catenella impudica (Montagne) J. G. Agardh

Vernacular name: Unknown.

Literature: **96**, 197 (sub nom. *Lomentaria impudica*). **8**, 701. **31**, 495. **24**, 266. **109**, 744.

Distribution: Burma: mouth of the Salween River. Indonesia: Java (north coast). Pacific Ocean: northern Australia, Polynesia, Colombia. Atlantic Ocean: West Indies, Guayana, Brazil.

Use: Miss Post **109**, 744 was informed by Dr. Barkill as follows: "In the markets of Rangoon I found an abundance of dried *Catenella* on sale which the sellers said came from the Tenasserim coast. The commercial alga (*Catenella*) is prepared for eating by pouring boiling water over it. Then it enters into salads, eaten by the Burmese." Miss Post also stated that Dr. L. P. Khanna bought *Catenella* parcels of ¼ kg. in the market of Rangoon. These parcels contained all members of the Bostrychietum association, viz. *Bostrychia radicans* (Mont.) Mont., *B. binderi* Harv., *Caloglossa adnata* (Zan.) De Toni, *C. leprieurii* (Mont.) J. G. Ag., *Catenella impudica* (Mont.) J. G. Ag., and *C. nipae* Zan.

Catenella nipae Zanardini

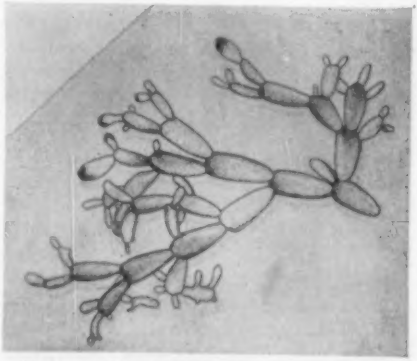

Fig. 13. *Catenella nipae*: part of plant, X 2.4 (after Dawson, 1954).

Vernacular name: Unknown.

Literature: **149**, 143-144, pl. 6A. **66**, 14. **108**, 69. **24**, 266. **109**, 744.

Distribution: Burma: Kuoy coast. Indonesia: Borneo (Sarawak), Aru I. New Guinea. Eastern Australia.

Use: Dr. L. P. Khanna wrote to Dr. Boergesen **24**, 226 about its use in Burma: "Some like it raw mixed with the oil of *Sesamum indicum* L., salt, powdered fruit of *Capsicum annuum* L., fried rhizome of ginger (*Zingiber officinale* Rose), onion (*Allium cepa* L.), and garlic (*Allium ursinum* L.); some boil it for an hour and then mix it with the above ingredients."

A chemical analysis of this species by Hooper **66**, 14 shows that half of its dry weight consists of carbohydrates and one-tenth of albuminoids.

Corallopsis Greville
Gigartinales, Gracilariaceae

The plants of this genus have a more or less cylindrical thallus of a cartilaginous substance which is however, somewhat folded and constricted at several places. The thallus is irregular, dichotomously branched, the branches taking rise in the constricted places. However, some of the branchlets are only developed as a kind of spine. The plants are light brown.

The species occurs in the lower part of the littoral and in the sublittoral region; one, *C. salicornia* var. *minor* was collected at a depth of 14.5-30 m. in the bay of Saleh near Sumbawa.

Corallopsis salicornia var. **minor** Sonder

Vernacular name: bulung buku (Bali).

Literature: Mertens ms. (sub nom. *Fucus salicornia*) **2**, t. 8 (sub nom. *Sphaerococcus salicornia*). **50**, pl. 53. **121**, 24, pl. 3. f. 6-11. **64**, 319. **128** quoted by Chapman **33**, 182 (sub nom. *Corallopsis minor*). **63**, 35. **31**, 657.

Distribution: Malay Peninsula. Indonesia: Sumatra, Bali, Solor, Paternoster I., Sumbawa, Flores, Ternate, Amboina, Sula Besi I., Kei I. New Guinea. Pacific Ocean: Tasmania, Thursday I., Marianas I.

Use: The plants are eaten as a vegetable in Bali. According to Hofstede **64**, 319 they can be used for the preparation of agar-agar.

Eucheuma J. G. Agardh
Gigartinales, Solieriaceae

Species of the genus have a cylindrical to flattened main axis and branches of a pale reddish color, drying to yellowish brown. Branching irregularly alternate to somewhat di- or trichotomous in appearance. Main axis and branches roughened by blunt nodules or spines which harbor the gametangia. The central tissue is composed of colorless filaments and surrounded by large cells grading to a small-celled epidermis. The general substance of the plants is firmly gelatinous to somewhat cartilaginous.

The seaweeds occur in the sublittoral region attached to a firm substratum.

Note: Members of the genus are used for making agar-agar. Burkill **31**, 1108 quotes the following passage from Logan's Journal (1851, p. 3): "It is recorded that algae for agar-agar made the bulk of the cargoes of Chinese junks returning home from Singapore. Much of the algae would be *Eucheuma*. The collecting grounds were the reefs and rocky ledges near Singapore. No export apparently exists now, but the alga is used locally in making agar-agar." Burkill further states: "Agar-agar is made in the chief centers on the coast of the Malay Peninsula, but to what extent this alga serves, or others of the genus, or *Eucheuma*, is unrecorded."

Eucheuma edule var. **major** Weber-Van Bosse

Vernacular names: agar-agar besar (Indonesia: Thousand I.); agar-agar halus (Celebes: Makassar).

Literature: **72**, 19, pl. 63 c-e (sub nom. *Chondrus edulis*). **142**, 263. **143**, 136, f. 33-34. **140**, 422, f. 170, pl. 15, 16.

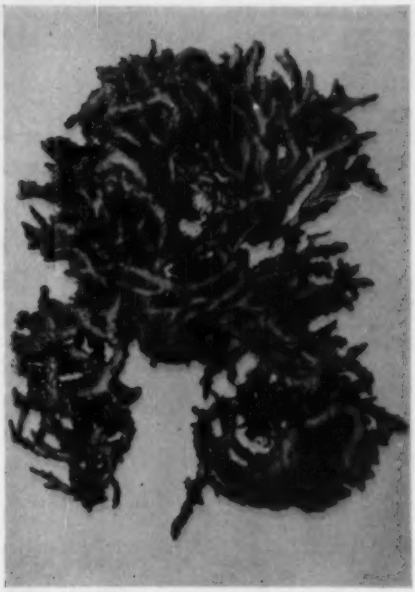

Fig. 14. *Eucheuma edule*: habit, X 0.7 (after Weber-Van Bosse, 1928).

Distribution: Indonesia: Thousand I., Sumenep, Kei I. Pacific Ocean: New Caledonia.

Use: The species is used by the inhabitants of Java (Thousand I.) in the preparation of jellies (agar-agar; cf. *E. muricatum* below).

Eucheuma gelatinae (Esper) J. G. Agardh

Vernacular name: Unknown.

Literature: **39**, 148, pl. 101, f. 5-7 (sub nom. *Fucus gelatinus*). **8**, 628. **88**, 46, 140 (sub nom. *Sphaerococcus gelatinus*). **12**, 27. **75**.

Distribution: Indian Ocean: Bourbon I. India. Indonesia. Philippines. Japan. New Caledonia. Australia.

Use: The seaweeds are used by the natives of the Philippines for making agar-agar (cf. *E. muricatum* below). Von Martens **88**, 46, 140 states: "To this purpose the fresh collected seaweeds are washed, dried, and afterwards boiled with sugar. They are then marketed in Manila. Mixed with *Lichen pulmonarius* the jellies are also used as a remedy against coughs."

According to Chapman **33**, 250 Lami **75** reports that this species with *Gloeopeltis coliformis* (most probably being a form of *G. furcata*) is used for agar production in Vietnam. The product replaces algin as a creaming agent in the manufacture of natural rubber.

Eucheuma horridum (Harvey) J. G. Agardh

Vernacular name: Unknown.

Literature: Harvey Alg. Telfair No. 12 (sub nom. *Gigartina horrida*). **8**, 625. **88**, 140. **63**, 34. **31**, 954.

Distribution: Indian Ocean: Mauritius I., Bourbon I. Malay Peninsula: Singapore. Indonesia.

Use: This species is used along with the other species of the genus in the manufacture of jellies (agar-agar) (Von Martens **88**, 46, 140).

Eucheuma muricatum (Gmelin) Weber-Van Bosse

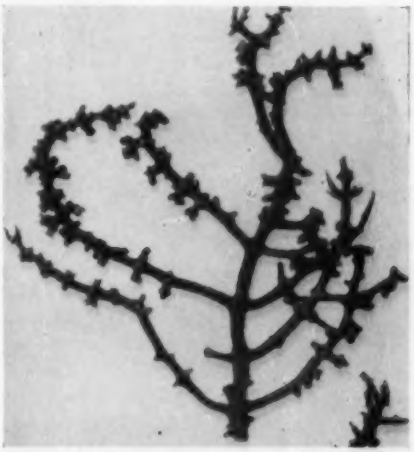

Fig. 15. *Eucheuma muricatum*: habit, X 0.7 (after Weber-Van Bosse, 1928).

Vernacular names: ruprupuue (Philippines: Union Prov.); agar-agar halus (Indonesia: Galadupa I.); agar-agar kasar (Indonesia: trade name at Makassar); agar-agar geser (Indonesia: Ceram); agar-agar pulu, agar-agar seru laut (Indonesia: Ceram-Laut); karang laut (Indonesia: Djakarta); gerang-gang (Indonesia: Lombok).

Literature: **47**, 111, pl. 6 (sub nom. *Fucus muricatus*). **84**, 313 (sub nom. *Fucus spinosis*). **7**, 16 (sub nom. *Eucheuma spinosum*). **140**, 413, f. 164, pl. 12, f. 1-5. **104**, 5 pl. 1, f. 1 (sub nom. *Eucheuma spinosum*). **88**, 140 (sub nom. *Eucheuma spinosum*). **12**, 27 (as *Eucheuma spinosum*). **135**, 406. **117**, 309 (*E. spinosum*). **64**, 319 (*E. spinosum*). **145**, 21 (*E. spinosum*). **36**, 130 (*E. spinosum*). **63**, 34. **31**, 954 (*E. spinosum*).

Distribution: Indian Ocean: Mauritius, Bourbon. India. Indonesia: widely distributed. Japan, Riu-Kiu I., Philippines. New Caledonia. Australia. Lord Howe I.

Use: *Eucheuma muricatum* is one of the most used species for the preparation of agar-agar in Malaysia, though it does not give in any way a good commercial product (De Groot **53**, 10). This is the reason why these seaweeds are only used by the natives themselves either alone or mixed with other agarophytes (cf. *Gelidium* and *Gracilaria*). According to Burkill **31**, 1109, Holmes in editing Meldrum's List of Johore medicines distinguishes "agar-agar karang" derived from *Gracilaria* from agar-agar derived from *Eucheuma spinosum*.

In Indonesia, especially in the Thousand Islands, the seaweeds being washed ashore are picked up from the beach or collected by divers at the end of the dry monsoon (September). They are dried on the coast and bleached in the sun and either marketed in Djakarta or boiled, after which the substance sets and can be hardened by drying into a solid gelatine-like pudding. This is eaten as a jelly. In W. Australia the seaweeds are used for the same purpose by the housewives. *Eucheuma* species are collected from the beaches, dried, and bagged and subsequently sold by the pound. (Ferguson Wood **41**).

Eucheuma serra (J. G. Agardh) J. G. Agardh

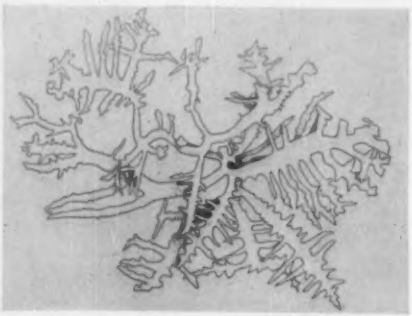

Fig. 16. *Eucheuma serra*: habit. X 0.4 (after Yamada, 1936).

Vernacular name: bulung djukut lelipan (S. Bali).

Literature: **6**, 17 (sub nom. *Sphaerococcus serra*). **8**, 626. **88**, 140. **63**, 34. **31**, 954.

Distribution: Mauritius. India. Indonesia: Java, Bali.

Use: Like the other species of the genus, *E. serra* is used in the preparation of agar-agar by housewives, and moreover, as a vegetable and as a medicine.

Gelidiella Feldmann et Hamel
Gelidiales, Gelidiaceae

Plants small to moderate in size, irregularly and sparingly alternately branched. The more or less cartilaginous main axes are cylindrical to somewhat flattened at the top. They arise from creeping stolons which are attached to rocks and coral debris. The central axis consists of a medulla of rather elongated cells grading into a cortex of smaller, often pigmented, cells. The tetrasporangia are regularly placed in the swollen ends of ultimate

branchlets occurring at the tips of the branches.

The plants occur on coral fragments and rocks in the supra-littoral region.

Note: The thallus of the genus *Gelidiopsis* has, in contradistinction to the genus *Gelidium*, no rhizoidal filaments.

Gelidiella acerosa (Forskal) Feldmann et Hamel

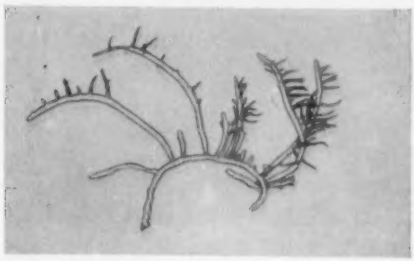

Fig. 17. *Gelidiella acerosa*: part of plant, X 1.2 (after Dawson, 1954).

Vernacular name: Unknown.

Literature: **43**, 190 (sub nom. *Fucus acerosus*). **40**, 533. **20**, 5 (sub nom. *Echinocaulon acerosum*). **37**, 422.

Distribution: Vietnam: Nha Trang, east of Cù Lào. Seems to occur in most tropical seas.

Use: Collected for food from rocks at low tide level.

Gelidium Lamouroux
Gelidiales, Gelidiaceae

The plants of this large and variable genus are flattened or cylindrical, with many, usually lateral, branches. The substance is cartilaginous. The main axis is erect, arising from a somewhat fibrous base. This axis is formed of long cylindrical cells (medulla) and a compact cortex of cells becoming smaller at the surface. Very slender refractive filaments (rhizines) are extant in this cortex. The organs of reproduction are immersed in swollen branches.

The plants occur on a firm substratum, especially coral fragments, in the sublittoral region in exposed places.

Note: The dried gelatin-like substance derived from *Gelidium* species and certain other red seaweeds is nowadays named agar-agar (Malaysia) or kanten (Japan). However, in the days of Rumphius the name agar-agar was already applied to the seaweeds themselves by the Indonesian inhabitants.

At present there is a tendency to refer to the agar-bearing seaweeds as agarophytes (Tseng **131**).

The meaning of the word agar-agar is not known; the word kanten is Japanese for "cold sky." This name was given because frost was necessary for the preparation at that time. Various other names exist, i. e. Bengal isinglass, Bengal isinglass gum, Chinese moss, Ceylon moss, Japanese isinglass, vegetable isinglass, etc.

The original preparation of agar-agar depended entirely upon natural means employed by the Japanese. The other orientals prepared it in the same way except that it was not frozen. The agarophytes are collected by divers and simply dried and bleached in the sun on the beach. Then the seaweeds are boiled with several times their weight of water. Sometimes some vinegar or coconut milk is added. After straining, the extract is ready to eat.

In the case of seaweeds sold to Japanese factories, which are situated in mountainous areas, the dried seaweeds are successively cleaned, washed in fresh water, and drained and bleached on bamboo frames. Subsequently, the agarophytes are fused into sheets, and the jelly is extracted by boiling. After straining, the jelly is poured into wooden trays and allowed to cool. At a certain stage of this process the hardening jelly is cut into bars of a certain size.

The most important use for agar-agar is in microbiological culture media, but it is extensively used for human and ani-

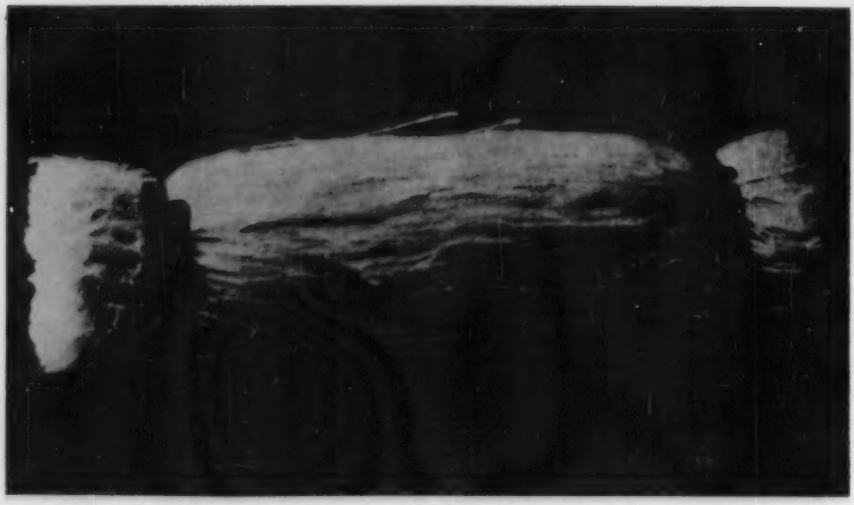

Fig. 18. A bundle of "slender" kanten made in Japan from algae of the genus *Gelidium* (after Smith, 1905).

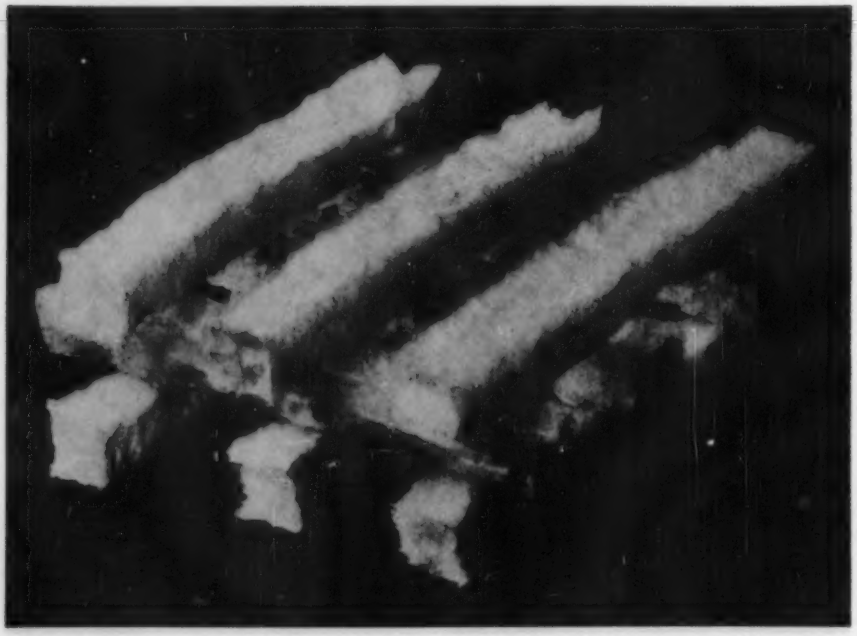

Fig. 19. Bar or "square" kanten made in Japan from algae of the genus *Gelidium* (after Smith, 1905).

mal food as roughage, as a stabilizer in bakery and dairy products, and in making jelly desserts, confectioneries, icings, and salad dressings. Agar-agar is employed in canning meat and poultry, in laxative preparations, as a constituent of medicinal tablets, pills, and capsules, in numerous pharmaceutical emulsions and ointments, in cosmetic creams and jellies, in paints and varnishes, in wire drawing lubricants, in liquor clarification, and in creaming of latex, and as a dental impression mold base, etc. cf. **154** and **155**.

Matsui **89** made an analysis of various species of *Gelidium*. His results, in percent of dried material, are as follows:

Ash	4.23
Lime	0.28
Magnesia	0.52
Nitrogen	2.01
Crude Protein	12.56
Fiber	17.89
Galactan	23.70
Pentosan	2.30
Methyl Pentosan	0.93
Reducing sugars after hydrolysis with dilute acid	23.20

In Japan, the most important source of agar-agar from a standpoint of quality as well as quantity is the seaweed *Gelidium amansii* (Adams **1**).

Gelidium amansii (Lamouroux) Lamouroux emend. Okamura

Fig. 20. *Gelidium amansii*: X 1 (after Okamura, 1932).

Vernacular names: Japansche scheleiachtige mos, steen- or klipbloem (old Dutch names used in Indonesia); hay tsay, olus marinus, sajur laut, tschintschau, tschoo-hoae (used in several parts of Indonesia, but especially in the island of Amboina).

Literature: **76**, 48, pl. 26, f. 2-5 (sub nom. *Fucus amansii*). **78**, 41. **102**, 52, pl. 19-22, 31, f. 3-7. **114**, 90 (sub nom. *Muscus gelatinus japonensis*). **88**, 41, 44, 94. **90**, 54. **31**, 1063.

Distribution: Indian Ocean: Madagascar, Mauritius. Malay Peninsula: Paknam (Thailand), Singapore. Pacific Ocean: Japan, Baschi I. (S. China Sea), Philippines. Moluccas. Atlantic Ocean: American coast.

Use: Rumphius **114**, 90 states as follows: "Take a handful of this moss and put it into a cup filled with fresh water for two days, adding a little vinegar. Filter the substance by means of thick muslin. The thick gelatinized part must be cooled and afterwards cut into pieces. Eat some of these pieces after pouring into rose water. The other pieces may be stored by keeping them extremely dry. They may be eaten after adding some fresh water. It is said by some people that the sea-smell of the seaweeds can be removed by adding lime water."

Gelidium latifolium Bornet

Vernacular name: limu loloa (Hawaiian I.).

Literature: **28**, 58, pl. 20, f. 8-10. **110**, 87. **31**, 1063.

Distribution: Malay Peninsula. Indonesia: Java, Timor. Pacific Ocean: Japan, China Sea, Hawaiian I., American coast. Atlantic Ocean: European coast (incl. Mediterranean), African coast.

Use: The species is collected for the manufacture of agar-agar. A chemical analysis of a sample from the south coast of Java shows that 23.1% agar-agar was present.

Gelidiopsis Schmitz
Gigartinales, Gracilariaceae

Plants forming more or less dense tufts of moderate size, creeping with its decumbent base upon broken corals, shells, and rocks. Some of the cylindrical irregularly inserted branches are very regularly pinnate or bipinnate. The terete thallus is of a cartilaginous consistency. The axis of the plant consists of a medullary tissue of thick-walled subcylindrical cells surrounded by an outer layer of densely placed small cells. An apical cell is present in the apex of the plant. Tetrasporangia occurring in the swollen conical upper apices of the ultimate branchlets.

The plants are common in the intertidal zone.

Gelidiopsis rigida (Vahl) Weber-Van Bosse

Vernacular names: sangau (Riouw-Lingga Archipelago); intip-intip, kembang karang (Java: Bantam).

Literature: **133**, 46 (sub nom. *Fucus rigidus*). **50**, 57 (sub nom. *Gelidium rigidum*). **139**, 104. **64**, 321 (sub nom. *Gelidium rigidum*). **128**, quoted by Chapman **33**, 182. **63**, 34 (sub nom. *Gelidium rigidum*). **31**, 1064 (sub nom. *Gelidium rigidum*).

Distribution: Malay Peninsula. Indonesia: widely distributed. Philippines: Panay I. In all warmer seas.

Use: This is one of the chief algae collected in Malaya and Indonesia for the preparation of agar-agar. The agar-agar content of a sample from the south coast of Java was 24.4%.

Note: Formerly this species was mostly described as belonging to the genus *Gelidium*. However, the absence of hyphae in the center of the thallus and the location of the stichidia indicate that it belongs to the genus *Gelidiopsis*.

Although this species is not very common in the Riouw-Lingga Archipelago, it is considered of greater value than *Gracilaria lichenoides*.

Gigartina Stackhouse
Gigartinales, Gigartinaceae

This genus is mentioned by Burkill **31**, 1070 for the usefulness of one of the species. The author writes of an unnamed species: "They are edible and enter into the agar-agar industry a little." However, the genus *Gigartina* is not yet recorded for Malaysia; it occurs in the temperate regions only. There it is used for the preparation of agar-agar, as in England.

Moreover, Burkill states: "A species of *Gigartina* has been recorded as growing in Singapore; but it is not quite clear what specific name it should bear." Most probably this species will be *Gigartina horrida* J. G. Ag., mentioned by Von Martens **88**, 30. As can be seen above, this species has to be transferred to the genus *Eucheuma*, its name being now *Eucheuma horridum* (Harvey) J. G. Agardh.

Gracilaria Greville
Gigartinales, Gracilariaceae

The plants of this widely distributed genus are bushy and irregularly or dichotomously branched. The branches are compressed or flattened. The whole plant is of a firm cartilaginous substance, horny when dry.

The thallus consists of two layers of cells, a central one (the medulla) of large, angular, colorless cells and a cortical one of small assimilative cells. Sessile on the branches are the cystocarps, containing the sexually produced spores; they form prominent swellings. Tetrasporangia scattered among the cortical cells.

Plants light pink to purplish. Occurring on rocks and broken corals in the littoral region.

Note: The identification of the different species is very difficult owning to the high variability of the plants.

Several species of Gigartina are most extensively employed for the manufacture

of agar-agar. It is, however, only in recent years that the value of especially *G. confervoides* as a commercial source of agar-agar has been duly recognized and well established. This species has already been used for several hundreds of years in Japan in manufacturing agar-agar, but it was merely used as a supplementary product of secondary quality. Recent investigations in America, South Africa, and Australia have definitely shown that *Gracilaria* species have their appropriate place in agar-agar manufacture. (See note under *Gelidium* for short summary of the applications of agar-agar.)

Because of the wide range of variation, the identification of discrete species in the genus *Gracilaria* is particularly difficult. If a monographic study of the genus is started, it is my opinion that many species described will be found to represent merely geographical and ecological forms.

Gracilaria confervoides (L.) Greville

Fig. 21. *Gracilaria confervoides*: plant with cystocarps, X 0.5 (after Chapman, 1950).

Vernacular names: gulaman, guraman, gulaman dagat. (Philippines: Luzon), Celyon moss (British Commonwealth), nuoc-mam, rau-cau, xdă-xoi (Vietnam).

Literature: **83**, 1629 (sub nom. *Fucus confervoides*). **50**, 123. **15**, 839; ed. 2, **15**, 580; ed. 3, **15**, 260 (sub nom. *Fucus edulis*). **88**, 43. **117**, 309. **144**, 267 (sub nom. gulaman dagat). **91**, 41. **145**, 21. **54**, 137. **31**, 1108. **135**, 100.

Distribution: Nearly cosmopolitan.

Use: The seaweeds are used as a food in two ways: (1) washed free from salt and eaten as a salad either raw or boiled, and (2) sun-bleached, dried, and marketed as a cheap substitute for gelatine. In Manila the seaweeds are brought into the markets during the rainy season. They are frequently used as food in the Philippines.

For domestic agar-agar production in Vietnam this species is collected along the shores from March to April, washed in fresh water, kneaded to slices and exposed to the sun (Gruvel **54**, 137). When prepared as food, *G. confervoides* is either boiled and eaten with some fish as nuoc-mam or sweetened as xoa-xoa.

"In Australia agar-agar of excellent quality, better in some respects than Japanese agar-agar, can be produced at the factories from *Gracilaria confervoides*" (Ferguson Wood **41**, 34). The same species is used in the industry on the Atlantic coast of North America and along the coast of the Gulf of Mexico.

According to Ferguson Wood **41**, 34 the Australian *Gracilaria* agar-agar forms an excellent growth medium for bacteria, especially haemophils and other pathogens. In that country the agar-agar is preferred by meat canners and cordial makers. Moreover, it is quite useful for dental use.

An analysis of a firm jelly prepared in the Laboratory of Organic Chemistry, Manila, showed the following (Wells, **144**, 268):

Moisture	99.37%
Ether extract	0.10%
Protein	0.10%
Ash	0.04%
Starch	none
Carbohydrate by difference	0.39%

The conclusion was reached that "gulaman dagat" is unsuitable for use in bacteriological work, owing to its low crushing pressure.

In India, Madras Presidency, the cast species of *Gracilaria* are used as a fertilizer as is stated by Chidambaram and Unny **34**, 67. An analysis gave the following values:

Moisture (air dry sample)	10.71%
Loss on ignition	71.59%
Insolubles	2.41%
Solubles	15.29%
Nitrogen	1.48%
Potash	0.66%
Phosphoric acid	0.07%

The *Gracilaria* species washed ashore are dried and applied together with *Sargassum* and *Turbinaria* species as manure in coconut plantations. The algae are placed around the palm three to four feet away and then covered with earth. Some experiments on a compost prepared by mixing seaweeds, fish offal, and shark liver sediment were undertaken with a hopeful result.

According to a letter of the Director of Fisheries at Colombo, Ceylon, both *G. confervoides* and *G. lichenoides* are sold as "Ceylon moss" at Rs 2/50 a pound (dry weight after cleaning) and are the chief sources of agar-agar (1949). Several thousand pounds are available in Ceylon.

Gracilaria crassa J. G. Agardh

Vernacular names: conji parsi (India: Tamil name); susueldot-baybay (Philippines: Union Prov.); rau cau chung vit (Vietnam).

Literature: **8**, 417. **117**, 309. **145**, 21. **37**, 438, f. 486.

Distribution: Indian Ocean: Ceylon. India: Pamban area. Thailand: Trúóng Dông. Philippines: Union Prov. Indonesia: Java (south coast), Celebes.

Use: The species is collected for food in Vietnam and is eaten in Union Province, Philippines.

Gracilaria eucheumoides Harvey

Fig. 22. *Gracilaria eucheumoides*: part of plant, X 1 (after Dawson, 1954).

Vernacular names: cauot-cauot, kauat-kauat (Philippines: Union Prov.).

Literature: **57**, 311. **117**, 309. **145**, 21. **54**, 137. **31**, 1108. **37**, 438, f. 48e.

Distribution: Vietnam, Nha Trang, Malay Peninsula. Indonesia: Java, Celebes, Lombok, Sumbawa, Flores, Roma I., Amboina. Pacific Ocean: Japan, Philippines, Friendly I. Indian Ocean.

Use: In Nha Trang (Vietnam) the species is considered edible, but it does not occur abundantly enough to be specially collected. In the Philippines the species is eaten raw as a salad or cooked as a vegetable.

Gracilaria lichenoides (L. ex Turner) Harvey

Vernacular names: conji parsi (India: Tamil name); chan-chow parsi (Ceylon); gargararao (Philippines: Ilocos Prov.); agar-agar karang (Johore); dujung (Lingga Archipelago) djanggut dujung (Riouw Archip.); bulung embulung (Java, Bali); bulung tombong puti (Lombok); sajor karang, djanggut monjet (Indonesia); aysana, aytsana, lotu-lotu putih (Amboina); rume yar waccar, callocane, dongi-dongi, donge-donge, gose, sango-sango (Celebes: Makassar).

Literature: Linnaeus in Herb. (sub nom. *Fucus lichenoides*). **132**, pl. 113, f. a (sub nom. *Fucus lichenoides*). **59**, 445. **114**, 181 (sub nom. *Alga* sive *agar coralloides prima*). **88**, 140. **60**, 323. **42**, 2. **35**, 250. **117**, 309. **91**, 41. **64**, 319. **145**, 21. **36**, 219. **128**, quoted by Chapman **33**, 182. **63**, 34. **31**, 1108.

Distribution: Widely distributed in the tropical regions of Southeast Asia. Indian Ocean: Mauritius. Pacific Ocean: Japan, most Pacific Islands, Australia, Tasmania.

Use: In Amboina the species is collected at the end of the dry monsoon. The seaweeds are washed in fresh water and pressed out with the hands. The gelatin-like remainder is either eaten as "atjar," a kind of pickle, or as "dabbo-dabbo," a sauce of lemon juice and ginger.

According to Crawford (quoted by Burkill **31**, 1108) in 1820, dried algae were already exported from Malay to China. In 1851, in Logan's Journal (vol. 5, 33), it is recorded "that algae for agar-agar made the bulk of the cargoes of Chinese junks returning home from Singapore, but much of the algae would be *Eucheuma*."

Ridley **113**, 270 reports that medical officers in Johore and Singapore adopted agar-agar for poulticing swollen knee joints and unhealthy sores.

A type of soup, pudding, and jelly is prepared from chan-chow parsi by the Ceylon fishermen. As already mentioned above, this species is used in the agar-agar industry, though not to such an extent as *G. confervoides*.

Gracilaria lichenoides f. **coronopifolia** (J. Agardh) May.

Vernacular names: limu manauea (Hawaiian I.); guraman (Philippines: Ilocos Prov.); gulaman, (Philippines: Visayans).

Literature: **8**, 592-3 (sub nom. *G. coronopifolia*). **89a**, 37, pl. 6. **121**, 55 (sub nom. *G. lichenoides* var. *cornicula-ta*). **110**, 87. **94**, 47, f. 14, no. 5.

Use: The plants of this variety are eaten both raw and cooked. It is eaten with salt and tomatoes, either fresh or after dipping it in boiling water; sometimes also in combination with onions and vinegar.

The species is only found at certain seasons of the year. After gathering, it is, without being washed in fresh water, dried in the sun and stored away for future use. When needed, the seaweed is soaked for a day, cleaned, chopped into small pieces and eaten (Miller **94**, 47).

In Hawaii this variety is often found drifted on the sand or rocks (Reed **110**, 87).

Gracilaria taenioides J. G. Agardh

Vernacular name: djanggut dujung (Banka Street).

Literature: **8**, 593. **64**, 319. **128**, quoted by Chapman **33**, 182. **63**, 35. **31**, 1108.

Distribution: Indian Ocean: Ceylon. Malay Peninsula. Indonesia: Banka Street, Riouw Archipel. Pacific Ocean: Korea, Japan, Australia.

Use: The species is used in Singapore in making a kind of agar-agar.

Grateloupia C. A. Agardh
Cryptonemiales, Grateloupiaceae

The plants are bushy and of moderate to considerable size, viz., up to 60 cm. high. The branching is generally pinnate and complanate. The branches are flattened in the middle part and tubular at the base and the tips. The texture of the thallus is fleshy to membranous. A medulla is present consisting of slender anastomosing filaments surrounded by a jelly, and a cortex of moniliform filaments, loosely or solidly united with mucus. Gametangia scattered over the surface. Reddish brown to violet.

Occurs in shallow water of the littoral region on a firm substratum.

Grateloupia filicina (Wulfen) C. A. Agardh

Fig. 23. *Grateloupia filicina*: habit, X 0.3 (after Lucas and Perrin, 1947).

Vernacular name: limu pakaeleawaa (Hawaiian I.: Oahu); limu huluhuluwaena (Hawaiian I.: Hawaii, Maui and Oahu).

Literature: **147**, 157, pl. 15, f. 2 (sub nom. *Fucus filicinus*). **3**, 223. **15**, 839; ed. 2, **15**, 580; ed. 3, **15**, 260. **88**, 46. **110**, 87.

Distribution: India: Pamban area. Indonesia: Java. Philippines: Batan I. Hawaiian I. Cosmopolitan.

Use: The natives of the Batan Islands market the seaweeds in Ilocos Province, where they are eaten. The gelose of the chopped algae has a coloring effect upon clothes.

Setchell **118**, 99 records that the species has a pleasant flavor even to one unaccustomed to eating seaweeds. In the Hawaiian Islands the seaweeds belonging to this species are eaten with limpets.

Halymenia C. A. Agardh
Cryptonemiales, Grateloupiaceae

The plants consist of a compressed, flat thallus of moderate to considerable size (up to 50 cm. long), which has a soft fleshy consistency. The branching is dichotomous to pinnatifid. Structurally the thallus shows a few slender filaments embedded in a soft jelly scattered through the surface cellules.

The plants are found on coral reefs in the littoral region.

Halymenia durvilliae var. **formosa** (Kuetzing) Weber-Van Bosse

Vernacular names: gamet (Philippines: Union Prov.); limu lepeahina (Hawaiian I.)

Literature: **29**, pl. 15. **72**, 33, pl. 91 (sub nom. *Halymenia formosa*). **140**, 235. **110**, 87. **117**, 309 (sub nom. *Halymenia formosa*). **145**, 21 (sub nom. *Halymenia formosa*). **36**, 130 (*H. formosa*). **31**, 1126 (*H. formosa*).

Distribution: Indian Ocean. Indonesia: Celebes, Kawio I., Sula Besi I., Ceram; New Guinea (Waigeu I.). Pacific Ocean: Japan, China Sea, Philippines: Luzon. Friendly I., Australia.

Use: The species is eaten in the Philippines and in the Hawaiian Islands (Reed **110**, 87).

Hypnea Kuetzing
Gigartinales, Hypneaceae

The bushy plants consist of a fleshy cylindrical thallus which is alternately branched. The longer branches are frequently incurled at the tips, the shorter ones often spine-like, acute. The central

axis (medulla) is segmented and surrounded by a cortex with larger cells toward the center and minute colored ones toward the surface. Gametangia situated in swollen branches. Brown to yellowish red. Subcartilaginous.

The plants occur in the lower part of the littoral region where the water is quiet, and in rock pools.

Hypnea cenomyce J. G. Agardh

Vernacular name: Unknown.

Literature: **8**, 452. **63**, 35. **31**, 1218.

Distribution: Indonesia: Borneo, Sulu Archipelago. Philippines. Australia.

Use: The species is eaten in Indonesia.

Hypnea cervicornis J. G. Agardh

Vernacular names: culot (Philippines: Ilocos Prov.); bulong djadja (Bali).

Literature: **8**, 451. **64**, 319. **128** quoted by Chapman **33**, 182. **63**, 135. **31**, 1218. **36**, 129 (?).

Distribution: Indonesia: Bali, Tawi-Tawi I. Philippines: Ilocos Prov. Occurring in most warmer seas.

Use: Hofstede **64**, 320 records that the seaweeds after being brought ashore are dried on the white coral beach for three days. Subsequently they are washed in fresh water and again exposed to the open for three days. The seaweeds then turn yellow-white. After boiling, filtering, and cooling the jelly is eaten with aren (palm sugar) and rasped coconut. Prepared in this way, it is marketed in the "pasars" at Bali.

Preliminary investigations carried out at Bogor, Indonesia, have shown that the agar-agar content of the Indonesian seaweeds belonging to this species is very low.

Hypnea divaricata Greville

Vernacular name: arien (Amboina).

Literature: **50**, 59. **114**, 186 (sub nom. *Agarum lactucurium* sive *Lactuca marina*, Agarum IV). **60**, 323. **88**, 43, 140. **90**, 56.

Distribution: Philippines: Zamboanga. Indonesia: Sumatra, Timor; New Guinea. Seems to occur in all warmer seas.

Use: The algae are eaten in Amboina. According to Von Martens **88**, 43, 140 this species is used in Timor for the preparation of domestic agar-agar.

Hypnea musciformis (Wulfen) Lamouroux

Fig. 24. *Hypnea musciformis*: plant with cystocarps, X 0.7 (after Weber-Van Bosse, 1928).

Vernacular name: wormroos (used by the Netherlanders in Indonesia).

Literature: **147**, 154, pl. 14, f. 3. (sub nom. *Fucus musciformis*). **78**, 43. **49**, 167. **31**, 1218. **135**, 100.

Distribution: India: Pamban area. Malay Peninsula: Singapore Philip-

pines: Negros I. Indonesia: widely distributed. Seems to occur in all warmer seas.

Use: According to Greshoff **49**, 167 this species is used as a vermifuge in some parts of Indonesia. It is not mentioned as a source for the manufacture of agar-agar in Malaysia. However, in Australia it is stated (Ferguson Wood **41**, 10) that: *"Hypnea musciformis* gives an excellent bacteriological agar. It has a very low viscosity and a setting point just about 30° C. (86° F.)." In Indonesia, preliminary chemical investigations carried out in the Laboratory of Chemical Research at Bogor have shown that the species has an agar-agar content of 30%.

Velasquez **135**, 100 states that this species is sold in the fresh state in the markets on the Philippines, or it is boiled for hours until gelatinized when the resulting liquid is sieved.

Gymnogongrus Martius
Gigartinales, Phyllophoraceae

The repeated forked, bushy plants are coriaceous in texture. Height up to 10 cm. The branches are compressed or flat, consisting of a central axis or colorless cells and a peripheral layer of smaller, closely packed assimilative cells, arranged perpendicular to the surface. Gametangia immersed in swollen branches. Purple to dark red.

Species are found in the lower part of the littoral region (Zaneveld's baso- and semi-littoral belt **151**).

Gymnogongrus javanicus Sonder

Vernacular name: limu koele (Hawaiian I.).

Literature: **121**, 3. **87**, 476. **140**, 438 (sub nom. *Gracilaria wrightii*). **128**, quoted by Chapman **33**, 182 (sub nom. *Gracilaria wrightii*).

Distribution: Indonesia: Buru I., Nusa Kembangan I. Hawaiian I. Seems to occur in all tropic seas.

Use: In Hawaii this "dry or hard limu" is eaten raw as a salad or relish.

Note: According to Reed **110**, 87 *G. vermicularis* var. *americana* J. Ag., and *G. disciplinaris* (Bory) J. Ag. are eaten in the Hawaiian Islands. The former species is usually called limu uaualoli, but it is also known as limu ekahaekaha and limu koeleele, whereas the latter is known under the names limu awikiwiki and limu nei.

Laurencia Lamouroux
Ceramiales, Laurenciaceae

The bushy plant consists of a much branched cylindrical or flattened thallus. The branching is often alternate or pinnate. A central axis is only visible at the apices of the branches, and consists of elongated longitudinal cells. Gametangia distributed over the surface of the branchlets. Rosy-purple, fading to yellow. Fleshy to cartilaginous.

Occurring on a firm substratum in the littoral and sublittoral region.

Laurencia botryoides (Turner) Gaillon

See Figure 25.

Vernacular name: Unknown.

Literature: **132**, 103, 178 (sub nom. *Fucus botryoides*). **45**, 15. **88**, 32. **31**, 1323.

Distribution: Malay Peninsula: Singapore. Japan, China, Australia, Tasmania.

Use: Burkill **31**, 1323 states that the species is not known to be eaten in Malay, though elsewhere several species of this genus are used for human food.

Laurencia obtusa (Hudson) Lamouroux

Vernacular name: sangau

Literature: **71**, 586 (sub nom. *Fucus obtusus*). **78**, 433. **128**, quoted by **33**, 182.

Fig. 25. *Laurencia botryoides*: a. plant, X 0.3; b. part of a pinnule; c. tetraspore; d. ramulus bearing male saucers; e. flocci from the same (after Harvey, 1860).

Distribution: Indonesia: Lingga Archipelago. Seems to occur in all warmer seas.

Use: Only known as edible in the Lingga Archipelago.

Laurencia papillosa (Forskal) Greville

Vernacular names: limu maneonea, limu lipeepee (Hawaiian); tartariptip (Philippine I.: Ilocos Prov.); layalaya (Philippines: Visayan).

Literature: **43,** 190. **50,** 52, **110,** 88. **94,** 47, f. 14, 2.

Distribution: Pacific Ocean: Philippines, Sandwich I., Hawaiian I. Atlantic Ocean: from Bermuda and Florida to Brazil.

Use: The species of *Laurencia* are liked by both Hawaiians and Filipinos. The seaweeds are eaten raw with tomatoes or, after hot water has been poured over them, they are combined with mashed tomatoes and eaten cold.

An analysis (Collado **36**) of an unidentified *Laurencia* species, named culot by the natives, was carried out at the College of Philippine Agriculture. The chemical composition is as follows:

Moisture	9.33%
Protein	8.62%
Ether free extract	53.79%
Ether extract (fat)	1.21%
Crude Fiber	8.38%
Ash	18.66%
Iodine	0.44%

Note: Other species of *Laurencia* eaten in the Hawaiian Islands are *L. pinnatifida* (Gmel.) Lamour., *L. perforata*

Fig. 26. *Laurencia papillosa*: part of a plant, X 3 (after Dawson, 1954).

Mont., *L. obtusata* (Huds.) Lamour., and *L. virgata* (Ag.) Ag. (cf. Reed **110**). All these species have the same vernacular names.

Reed also remarks that the several *Laurencia* species are generally called limu maneoneo, if coarse and short, and limu lipeepee if finer and longer. Limu lipee is an abreviation, while limu lipuupuu has only local use in places on Hawaii and Maui.

Liagora Lamouroux
Nemalionales, Helminthocladiaceae

The species form rather compact tufts. They are mostly dichotomously, but also laterally, branched. Surface farinaceous, but covered by a calcareous deposit. When decalcified, the axial, longitudinal branching can be easily seen. The corticating filaments hardly extend beyond the calcification, hence the absence of a distinct color. The assimilating filaments are moniliform. Gametangia in node-like discs on the upper part of the frond. Older plants look like coralline algae, but they are not so stiff and brittle.

The species show much variation in habitat. Occurring on rocks and broken pieces of coral in the littoral region.

Note: In accordance with the studies carried out by Boergesen **17**, 59, and with the notes by Mrs. Weber-Van Bosse **140**, 491, the species *Liagora cheyneana* Harv. is regarded here as a variety of *Liagora farinosa* Lamx.

Liagora farinosa var. **cheyneana** (Harvey) Zaneveld

Vernacular name: baris-baris (Philippines: Union Prov., Ilocos Prov.).

Literature: **79**, 20. **59**, 552 (sub nom. *Liagora cheyneana*). **117**, 309 (sub nom. *Liagora cheyneana*). **145**, 21 (sub nom. *Liagora cheyneana*).

Distribution: Philippines. New Guinea. Seems to occur in all warmer seas.

Use: Only known as edible in the Philippines.

Fig. 27. *Liagora farinosa*: habit, X 1 (after Dawson, 1954).

Note: Reed **110** mentions still another species, *L. decussata*, from the Hawaiian I. with the vernacular name limu puaki, which is eaten there.

Rhodymenia Greville
Rhodymeniales, Rhodymeniaceae

These plants have a flat frond which is dichotomously or palmately divided at wide angles. The interior cells are large and uncolored, the cortex being composed of minute, colored, small cells. Gametangia scattered over the thallus.

The species occur on rocks and dead pieces of coral in the littoral region.

Note: *Rhodymenia palmata* has not yet been described from a locality within the tropics of Cancer and Capricorn. However, it is mentioned in the present paper, as, according to a note by Mrs. Weber-Van Bosse **140**, 460, it is suspected to be identical with *Rhodymenia indica*. The variety *marginifera* from Java (Zollinger **161**, 3) of *R. indica* most probably is an exception.

Rhodymenia palmata (L.) Greville

Vernacular name: dulse (N. America, British Isles.

Literature: **83**, 1630 (sub nom. *Fucus palmatus*). **50**, 93. **49**, 167 (sub nom. *Rhodymenia palmata*).

Distribution: Indonesia. Nearly cosmopolitan.

Use: According to Greshoff **49**, 167 the seaweed is used as a vermifuge.

Sarcodia J. G. Agardh

Gigartinales, Sarcodiaceae

The plant consists of a flat, flabellately divided thallus, frequently shortly stipitate and provided with marginal prolifications. The prolifications are often again dichotomously divided and are gradually attenuated toward the base. Margins acute or dentated. Structurally the thallus shows a number of slender, long filaments and a cortex of cells gradually diminishing in size toward the surface. Gametangia are scattered over the surface of the thallus. Color, if dried, dark red; if fresh pink.

Occurring in the lower parts of the littoral region attached to a firm substratum, but also in the sublittoral region.

Sarcodia montagneana

(Harvey et Hooker fil.) J. G. Agardh

Vernacular name: bibiru (Lombok).

Literature: **59**, 544 (sub nom. *Rhodomenia montagneana*). **8**, 623. **140**, 428. **114**, 186 (sub nom. *Agarum secundum* sive *bracteatum*.) **62**, 139 (sub nom. *Fucus bracteatus*). **88**, 43 (sub nom. *Mastocarpus klenzeanus*). **60**, 323 (sub nom. *Mastocarpus klenzeanus*). **136**, 411. **90**, 53 (sub nom *M. klenzeanus*). **63**, 34 (sub nom. *Mastocarpus klenzeanus*). **128**, quoted by **33**, 182. **31**, 1965.

Distribution: Red Sea. Indian Ocean. Indonesia: Banka, Java, Timor, Amboina. Pacific Ocean: Japan, Australia, New Zealand, Pacific I., Cape Horn.

Use: Much used as food in the Moluccas.

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Scarcity of collected literature information limited the initial planning and selection of materials. The absence of any comprehensive treatises suited to needs of the program made difficult a systematic comparison of the characteristics and potentialities of the various plant families, with regard to either the quantity or quality of their seed protein. Consequently, an extensive literature survey on seed proteins was undertaken. The authors have endeavored to cover the literature through 1955 with regard to quantity of protein in seeds produced by various species and up to 1957 with regard to the amino acid composition of seed proteins. Compilations by Block and Weiss (15) and by Harvey (27) greatly facilitated the latter search. Material collected on amino acid composition is included in this paper along with a digest of the conclusions drawn from the survey. In addition, original data are presented on the amino acid composition of nine species of seeds for which such information was not found in the literature.

Comparison of Amino Acid Composition of Seed Proteins From Various Plant Families

Species Studied Experimentally. Data on amino acid composition were tabulated from the literature for 89 species, representing 25 families. Forty-eight of these species belong to only two families, the Leguminosae and Gramineae. In contrast, only one or two species had been analyzed in some of the families which included economically valuable crops, such as Cruciferae and Compositae. Data were also totally lacking on the amino acid composition of seeds which might be considered potential oilseed crops, such as some of the Umbelliferae and Labiatae. Consequently, several nutritionally important amino acids were determined by microbiological methods in seeds of 9 species belonging to various families: *Guizotia abyssinica* and *Vernonia anthelmintica* (Compositae), *Raphanus sativus* (radish) and *Eruca sativa* (Cruciferae), *Daucus carota* (wild carrot) and *Anethum graveolens* (Umbelliferae), *Luffa acutangula* (Cucurbitaceae), *Hibiscus cannabinus* (Malvaceae), and *Perilla frutescens* (Labiatae).

Table I includes the previously unpublished amino acid composition data in addition to literature values for all species for which published data were found. All amino acid composition data in Table I were recalculated to the basis of percentage of protein (i.e., g./16 g. N) if expressed in literature on some other basis.

The data are grouped according to botanical classifications. The nutritionally important amino acids included are: arginine, histidine, cystine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Only results published between 1952 and early 1957 were incorporated, except for certain species for which all existing amino acid composition data were older. Averages given by Block and Weiss (15) were accepted; data were added only from references not included in their averages. Only the following have been knowingly excluded: Certain references presenting values for only one or two amino acids have been omitted. The data of Bagchi, Ganguli, and Roy (6) on several species of legumes were omitted. In addition to presenting extraordinarily high lysine values for the species they examined (e.g. 10.0-13.6% based on total protein), these authors reported arginine or histidine as being absent from some species. Data of Baliga, Rajagopalan, and Shivaramaiah (8) on safflower also were omitted, because there was some doubt as to the mathematical basis used by the these authors in expressing their results.

Seed Protein Sources—*Amino Acid Composition and Total Protein Content of Various Plant Seeds*

An extensive literature survey on seed proteins has been made, with attention given to both amino acid composition of various seed proteins and the total quantity of protein produced by the seeds. Data have been grouped according to botanical classifications and correlations drawn where possible. The various plant families have been rated according to their protentialities as protein-producing seed crops in the United States. As a beginning towards filling in some obvious gaps in amino acid composition data, amino acid assays have been carried out for the first time on nine species of seeds.

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Introduction

One objective of an extensive research program on potential new crops initiated by USDA's Agricultural Research Service is the discovery and development of improved sources of vegetable protein. The ultimate goal of this research is the utilization of new plant materials for (a) more adequate fulfillment of feed, food, or industrial needs, (b) possible alternate crops for those presently produced in excess of need, or (c) cultivation where suitable crops are presently lacking.

A continuing need exists for ample sources of high-quality protein, especially on a world-wide basis. The discovery of new sources of plant proteins which are of good quality and which can be produced economically would be desirable. Although large portions of the world's population are dependent upon plant sources for their dietary protein, presently used vegetable proteins are generally deficient in one or more of the essential amino acids, especially lysine and methionine. This deficiency is also important in feeding nonruminant animals (5, 49, 50, 60). Corn, soybean meal, cottonseed meal, and linseed meal are widely used feedstuffs in this country. Of these four, only the soybean is adequate for the lysine requirements of nonruminants near the 20% protein level. All of these feedstuffs are deficient in methionine, and corn is deficient in tryptophan.

There is a distinctly limited knowledge of plant proteins. Possibly some might be found from which derived industrial products having particularly desirable characteristics could be economically produced. Such proteins should be sought that are especially suitable for presently known industrial applications or that have properties suitable for new uses. Nutritional character of new proteins under consideration for such uses would be of lesser consequence than other properties. Our ability to obtain them naturally in high yields and high concentrations would be particularly important. With these considerations in mind, investigation of a variety of seeds was planned with the objective of discovering plants which are superior sources of seed protein, qualitatively or quantitatively, and which show promise as potential new crops.

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Secale cereale	rye	C			1.7				2.2			2.0		Bergh, 1952 (14)
			4.6	2.1		—13.5—		3.5	1.1	4.0	3.0		4.2	Focke, 1956 (24)
		M	5.3	2.2		3.8	6.0	4.0	1.6	4.2	3.3	1.3	5.0	Lyman, 1956 (43)
Secale montanum			5.1	2.2		—10.3—		3.2	1.0	4.3	2.5		5.4	Focke, 1956 (24)
Setaria italica	foxtail millet	M,C	7.1	3.9		5.7	14.1	2.6	3.5	5.3	3.5	0.8	6.0	Chitre, 1956 (18)
		M	3.6	2.1		7.6	16.7	2.2	2.8	6.7	3.1	1.0	6.9	Ramachandran, 1956 (56)
		M				5.9	12.9	1.7	3.1	5.7	4.1	1.6	7.1	Baptist, 1956 (11)
Sorghum vulgare[2]	sorghum		3.4	2.5	1.6	5.2	16.1	2.0	1.6	4.8	3.4	1.1	5.6	Block, 1956 (15)
[9]		M,C	6.3	2.1		4.7	9.5	3.6	2.5	4.2	2.7	0.4	4.3	Chitre, 1956 (18)
		M	4.1	2.1		5.0	13.9	2.2	1.7	5.5	3.9	1.3	5.7	Lyman, 1956 (43)
Triticum spelta	spelt	M	4.8	2.1		4.4	7.0	3.0	1.7	4.8	4.0	1.3	4.9	Lyman, 1956 (43)
Triticum vulgare[2]	wheat		4.3	1.8	3.3	4.4	6.9	2.5	1.2	4.4	3.9	1.2	4.5	Block, 1956 (15)
		M,C	10.5	1.6		4.8	7.7	3.3	2.7	4.5	3.7	1.2	4.1	Chitre, 1956 (18)
[9]		PC	11.9	3.8		4.2	9.7	7.1	2.9	5.1	3.1		5.2	Holmes, 1953 (31)
		M	5.1	2.6		4.5	6.5	2.7	1.3	4.9	3.0	1.4	4.5	Lyman, 1956 (43)
Zea mays[2]	corn; maize		4.4	2.4	1.6	4.0	12.7	2.7	1.8	4.5	4.1	0.7	5.3	Block, 1956 (15)
[4]		M	4.3	2.7		4.2	12.9	3.2	2.1	5.1	3.7	1.0	5.3	Lyman, 1956 (43)
[10]		PC	5.8	3.7	3.3	6.0	15.0	4.5	5.2	8.1	6.8	1.0	5.7	Wolfe. 1957 (71)
2. Palmaceae (Palm family)														
Astrocaryum tucuma	tucum		9.4	1.7		3.4	6.0	4.3	0.9	3.4	2.6	0.9	3.4	NAS-NRS,1956 (48)
		M	9.5	1.5		3.4	6.0	4.8	1.1	3.1	2.2	0.8	3.4	Williams, 1955 (70)
Cocos nucifera	coconut	M	14.6	2.0		3.7	7.2	3.4	2.0	4.5	3.5	0.7	6.1	Raica, 1956 (55)
		M	10.8	1.6		4.7	7.9	3.0	1.5	3.9	2.9	1.0	4.9	Williams, 1955 (70)
Elaeis guineensis	oil palm	CC,C	11.0	1.8	1.7		5.5	6.7	1.2			1.7	4.4	Baudoin, 1950 (12)
Orbignya speciosa (=*O. cohune*)	babassu	M	14.0	1.8		3.9	6.2	4.3	2.3	5.9	3.1	1.1	5.2	Lyman, 1956 (43)
			12.6	1.7		5.1	6.3	4.2	1.5	4.2	2.9	0.8	4.8	Williams, 1955 (70)
II. DICOTYLEDONAE														
1. Amaranthaceae														
Amaranthus paniculatus		M	14.7	2.9		6.9	8.0	8.2	2.5	4.7	4.3	0.9	6.0	Ramachandran, 1956 (56)
		C			3.0				2.4					Subramanian, 1952 (64)
2. *Anacardiaceae*														
Anacardium occideniale	cashew	M	9.6	1.9		5.6	7.0	3.6	1.6	4.3	3.4	2.2	7.3	Raica, 1956 (55)
3. Chenopodiaceae														
Chenopodium pallidiculae	canihua	M	7.9	2.5		6.8	5.8	6.0	1.8	3.6	4.8	0.8	4.6	White, 1955 (69)
Chenopodium quinoa	quinua	M	7.4	2.7		6.4	7.1	6.6	2.4	3.5	4.8	1.1	4.0	White, 1955 (69)

TABLE I.

AMINO ACID COMPOSITION of SEED PROTEINS

Botanical Name	Common Name	Method of Anal.[1]	Percent amino acid in protein (16% N basis)											Author, Reference
			Argi-nine	Histi-dine	Cystine	Isoleu-cine	Leu cine[3]	Lysine	Methi-onine	Phenyl-alanine	Thre-onine	Trypto-phan	Valine	
I. MONOCOTYLEDONAE														
1. Gramineae (Grass family)														
Avena sativa[2]	oat		6.9	2.2	1.2	4.9	7.2	4.4	1.5	4.8	3.8	1.2	5.3	Block, 1956 (15)
[3]		M	6.6	2.0		4.3	6.8	4.1	1.2	4.8	3.7	1.4	5.7	Lyman, 1956 (43)
[4]		PC	8.1	2.6	1.6	—13.4—		3.7	1.6	5.7	3.4	1.2	5.3	Nehring, 1957 (51)
[5]		M						4.0	1.4					Weber, 1957 (68)
Brachiaria ramosa (=*Panicum ramosum*)	brown top millet	M				5.0	13.4	1.4	2.9	6.2	4.1	1.3	7.5	Baptist, 1956 (11)
Coix lacryma-jobi	Job's tears	M	3.5	2.2	1.8	7.2	23.7	2.5	3.1	4.8	4.2	0.5		Adrian, 1955 (1)
Eleusine coracana[6]	finger millet; ragi	M		1.5		6.4	9.5	3.4	3.9	4.4		1.6	6.7	Balasubramanian, 1952 (7)
		M				4.6	8.8	2.6	3.2	5.1	3.9	1.3	8.4	Baptist, 1954 (10)
		M			2.4			3.7	3.1			0.7		Jelliffe, 1956 (33)
Euchlaena mexicana[3]	teosinte	M						1.6	2.3			0.2		Melhus, 1953 (46)
Hordeum vulgare[2]	barley		4.9	1.9	2.4	4.4	6.7	3.6	1.5	4.9	3.5	1.2	4.7	Block, 1956 (15)
[4]		M	4.5	2.4		3.9	6.5	3.6	1.4	5.2	3.4	1.3	5.2	Lyman, 1956 (43)
[4]		PC	4.8	1.7	0.9	—12.9—		3.6	2.0	5.4	3.6	1.7	4.1	Nehring, 1957 (51)
		CC	4.6	2.7		4.7	6.8	4.1	1.6	4.3	3.6	1.3	6.4	Kimura, 1957 (36)
Oryza sativa[2]	rice		7.9	2.5	1.1	4.7	8.4	3.4	1.8	4.7	3.6	1.2	6.3	Block, 1956 (15)
		M,C	12.7	4.4		6.2	9.6	3.4	3.6	5.5	4.7	0.7	7.4	Chitre, 1956 (18)
[4]		M			2.3			3.7	2.1			0.6		Jelliffe, 1956 (33)
[4]		M	8.4	2.2		4.5	7.9	4.2	2.2	4.9	3.5	1.6	6.3	Lyman, 1956 (43)
		CC	8.0	2.3		5.3	9.1	4.9	1.9	4.9	4.2	1.3	6.6	Kimura, 1957 (36)
Panicum crus-galli (=*Echinochloa crus-galli*)		C	5.9	5.6	2.8			3.9						Ohara. 1937 (53)
Panicum miliaceum	millet, proso	M	2.9	1.9		4.0	10.1	2.1	2.5	4.9	3.6	1.4	5.1	Lyman, 1956 (43)
		M				4.6	11.6	1.7	2.7	6.0	3.7	1.0	7.2	Baptist, 1956 (11)
Panicum miliare		M				5.1	10.9	1.8	3.1	5.8	4.1	1.3	8.4	Baptist, 1956 (11)
		M	4.7	1.9		6.7	10.9	1.8	2.3	4.8	3.4	0.6	6.1	Ramachandran, 1956 (56)
Paspalum scrobiculatum		M	4.0	1.8		5.3	8.5	2.1	2.8	6.9	3.8	0.7	5.6	Ramachandran, 1956 (56)
Pennisetum typhoideum [7] (=*P. spicatum*) [8]	bulrush millet	M	3.6	2.0	1.3	5.0	16.8	2.7	2.4	3.9	2.7	1.8	4.4	Adrian, 1955 (1)
		M	4.7	2.1	1.3	4.3	17.4	2.6	2.6	4.9	4.9	2.3	5.7	
		M		1.5		5.9	9.5	3.8	1.8	4.3		1.9	6.3	Balasubramanian, 1952 (7)
		M,C	6.9	3.4		4.0	9.3	3.7	2.4	3.1	2.9	1.1	4.7	Chitre, 1956 (18)

Botanical Name	Common Name	Method of Anal.[1]	Percent amino acid in protein (16% N basis)										Author, Reference
			Argi-nine	Histi-dine	Cystine	Isoleu-cine	Leu cine	Lysine	Methi-onine	Phenyl-alanine	Thre-onine	Trypto-phan	Valine	
4. Compositae (Composite family)														
Carthamus tinctorius	safflower	M	7.8	2.0		3.9	5.5	2.7	1.5	5.3	2.9	1.2	4.9	Lyman, 1956 (43)
Guizotia abyssinica	niger	M	12.7	2.0		4.8	6.4	5.3	1.4	4.4	2.9		6.5	Authors' Unpublished data
Helianthus annuus[2]	sunflower		8.6	1.8	1.6	4.8	6.4	3.3	1.9	4.5	3.4	1.1	5.1	Block, 1956 (15)
		M	7.8	2.2		4.5	6.0	3.8	2.2	5.1	3.4	1.4	4.9	Lyman, 1956 (43)
Vernonia anthelmintica	ironweed	M	11.2	1.9		4.5	5.6	4.8	0.6	4.3	3.0		6.4	Authors' Unpublished data
5. Corylaceae (Hazel family)														
Corylus avellana[4]		M	14.9	1.8	0.4	6.3	6.2	3.0	0.8	3.5	2.7	1.1	6.4	Fang, 1953 (23)
		M	13.6	2.2		4.5	6.4	2.4	1.2	3.7	3.0	2.0	5.9	Raica, 1956 (55)
6. Cruciferae (Mustard family)														
Brassica arvensis (=*B. kaber*)	mustard	PC	7.5	1.9	1.3			3.8				1.1		Nehring, 1957 (51)
Brassica rapa	rape	M	5.6	2.6	1.7	3.7	5.7	3.5	1.1	4.0	3.8	2.0	5.7	Ågren, 1952 (3)
			7.2		1.9	4.5	8.7	5.4	5.3		4.8		6.5	Bell, 1955 (13)
		PC	5.0	3.0	0.7	—12.9—		2.6	1.5	5.1	4.0	1.6	4.7	Nehring, 1957 (51)
Eruca sativa	garden rocket	M	8.2	2.6		4.3	6.2	5.8	1.5	3.8	3.2		5.7	Authors' Unpublished data
Raphanus sativus	radish	M	11.2	2.6		4.8	6.7	5.8	1.6	4.3	3.7		6.3	Authors' Unpublished data
7. Cucurbitaceae (Gourd family)														
Cucurbita foetidissima	wild gourd	M	14.3	1.9		4.4	6.7	3.3	1.9	4.6	2.6	1.6	4.8	Lyman, 1956 (43)
Cucurbita pepo	pumpkin	M	11.0	2.1		3.6	5.4	5.1	2.1	4.3	2.3	1.5	4.2	Lyman, 1956 (43)
		M	15.4	1.8		5.9	8.0	2.7	1.1	5.3	2.8	1.6	5.0	Massieu, 1950 (45)
Luffa acutangula	luffa	M	14.4	1.7		4.3	5.5	3.7	0.8	3.5	2.2		5.2	Authors' Unpublished data
8. Euphorbiaceae (Spurge family)														
Aleurites fordii	tung	M	10.9	2.3		4.9	7.6	4.2	2.2	7.3	4.6	1.7	8.3	Lyman, 1956 (43)
Ricinus communis[4]	castor	M		2.5		5.3	7.2	3.1			3.6	0.8	6.6	Kodras, 1949 (38)
		M	11.5	1.9		5.0	6.0	3.2	1.6	4.9	3.5	1.3	6.1	Lyman, 1956 (43)
Ricinodendron rautanenii				2.6	4.1	7.9	6.2	5.1	2.0	4.6	7.9	1.2	7.1	Adrian, 1955 (2)
Sapium sebiferum	Chinese tallow tree	M	16.6	2.9	1.3	5.9	7.4	2.6	1.6	4.8	3.7	1.4	7.8	Holland, 1948 (30)
9. Fagaceae (Beech family)														
Quercus sp.	oak	M	5.9	2.0		4.6	6.6	5.2	1.1	3.9	3.5	1.0	5.9	Raica, 1956 (55)

10. Juglandaceae (Walnut family)														
Carya illinoensis	pecan	M	10.4	3.0	2.1	4.9	8.2	5.4	1.7	5.3	4.0	1.4	3.5	Edwards, 1955 (21)
		M	11.5	2.1		5.0	6.6	3.6	1.2	4.8	3.1	1.1	5.4	Raica, 1956 (55)
Juglans nigra	black walnut	C	11.8	3.5	1.7			2.9						Nollau, 1915 (52)
Juglans sp.	walnut	M	7.4	1.6		3.2	5.2	2.2	1.2	3.3	2.6	1.5	3.8	Lyman, 1956 (43)
		M	13.0	2.3		4.3	6.9	2.5	1.7	4.3	3.3	1.0	5.5	Raica, 1956 (55)
11. Labiatae (Mint family)														
Perilla frutescens		M	14.8	2.5		4.3	6.3	4.4	1.4	5.1	3.0		6.0	Authors' Unpublished data
12. Lecythidaceae														
Bertholletia excelsa	Brazil nut	M	13.2	2.2		3.8	6.7	2.1	5.5	3.3	2.3	1.0	4.8	Raica, 1956 (55)
13. Leguminosae (Legume family)														
Arachis hypogaea[2]	peanut;		10.9	2.5	1.4	4.0	6.1	3.5	0.8	5.1	2.7	1.2	4.9	Block. 1956 (15)
	groundnut		10.6	2.1	1.9	4.3	7.0	3.4	1.2	5.4	2.9	2.0	8.0	Hoffpauir, 1953 (28)
		C,M			1.4			3.4	0.9					Carpenter, 1952 (16)
		M	10.3	2.2		4.3	6.7	3.5	1.0	5.0	3.0	1.2	4.8	Lyman, 1956 (43)
Cajanus indicus	pigeon pea;													
(=*C. cajan*)	red gram	M	7.6	2.2		6.6	8.7	7.0	0.9	8.2	4.0	0.2	5.7	Chatterjee, 1956 (17)
		M,C	12.7	4.8		5.1	6.1	6.2	3.4	7.8	3.1	0.4	4.3	Chitre, 1956 (18)
		C			0.4			6.3	0.3	8.7		0.9		Esh, 1953, 1954 (22)
		M			0.5				1.9			0.2		Gupta, 1955 (25)
		M			1.8			7.4	2.2			0.4		Jelliffe, 1956 (33)
		M,C	5.4	3.4	0.8	5.7	7.0	6.4	0.9	9.1	3.4	0.2	5.2	Vijayaraghavan, 1953 (67)
Cicer arietinum	chick pea;													
	garbanzo;	M	7.6	1.4		5.7	6.7	5.4	0.9	3.7	3.2	0.5	4.5	Chatterjee, 1956 (17)
	Bengal gram	M,C	12.4	4.1		4.4	4.9	4.5	3.1	3.0	4.5	0.9	3.8	Chitre, 1956 (18)
		C			0.7			6.2	0.7	4.8	2.8	1.2		Esh, 1953, 1954 (22)
		M			1.0				2.3			0.2		Gupta, 1955 (25)
[11]		M			1.8			7.9	1.7			0.7		Jelliffe, 1956 (33)
		M	7.3	4.5		7.9	14.1	10.0	1.1	8.0	5.0	1.8	4.9	Khan, 1957 (35)
		M	9.0	2.6		5.1	7.4	6.3	1.8	6.8	3.7	0.8	6.3	Raica, 1956 (55)
		M,C	6.9	2.3	0.8	6.0	8.0	6.4	1.7	5.0	4.8	0.6	5.4	Vijayaraghavan, 1953 (67)
Cyamopsis tetragonolobus	guar		2.3	0.9		3.7	6.1	5.2	0.5	2.7	1.3	1.7	3.6	Block, 1956 (15)
[12]		PC	2.1	0.3	0.3	4.2	16.1	10.3	4.2	1.0	0.3	0.3	6.1	Ramakrishnan, 1957 (57)
Dolichos biflorus	horse gram	M,C	13.9	5.9		5.1	9.4	5.8	2.0	4.3	3.2	0.9	6.6	Chitre, 1956 (18)
		M			1.6			7.5	2.6			0.6		Jelliffe, 1956 (33)
		M	5.4	3.0		6.7	7.9	8.3	0.8	8.5	3.8	0.6	5.4	Ramachandran, 1956 (56)

Botanical Name	Common Name	Method of Anal.[1]	Percent amino acid in protein (16% N basis)										Author, Reference
			Argi-nine	Histi-dine	Cystine	Isoleu-cine	Leu cine	Lysine	Methi-onine	Phenyl-alanine	Thre-onine	Trypto-phan	Valine	
Dolichos lablab	hyacinth bean	M	9.2	2.8		6.0	9.0	8.1	0.7	5.4	3.3	0.5	5.6	Ramachandran, 1956 (56)
Enterolobium cyclocarpum		M	7.1	2.5		5.5	11.4	4.8	0.9	3.3	2.9	1.1	3.9	Massieu, 1950 (45)
Galega officinalis	goat's rue	PC	5.4	5.7		—11.0—		5.6	[12]	8.0	7.0		[13]	Kolousek, 1955 (39)
Glycine max[2]	soybean		7.0	2.5	1.2	5.8	7.6	6.6	1.1	4.8	3.9	1.2	5.2	Block, 1956 (15)
[11]		M	7.4	2.3		5.1	7.1	6.5	1.4	5.0	3.8	1.5	5.3	Lyman, 1956 (43)
		M			2.0			5.3	2.0			0.9		Jelliffe, 1956 (33)
		PC	6.0	2.5	1.6	—11.8—		4.2	1.8	6.4	4.9	1.3	5.7	Nehring, 1957 (51)
		CC	7.4	2.6		6.2	7.6	6.0	1.5	4.2	4.7	1.2	5.3	Kimura, 1956 (36)
Lathyrus sativus	chickling vetch	M	12.5	2.1		8.7	9.3	7.4	0.6	4.2	4.7	0.3	7.0	Chatterjee, 1956 (17)
		C			0.7			5.3	0.2	2.3		1.0		Esh, 1953, 1954 (22)
		M			0.5				0.7			0.3		Gupta, 1955 (25)
[14]			8.0	4.5	1.0			5.7	2.0			0.8		Klimenko, 1956 (37)
		M	7.9	2.5		6.6	6.6	6.9	0.4	4.1	2.3	0.4	4.7	Ramachandran, 1956 (56)
Lens esculenta	lentil	M				4.5	6.9	6.4	0.7	4.5	3.5	0.8	5.0	Baptist, 1954 (10)
		M	8.5	1.7		6.5	8.5	7.4	0.5	3.7	4.0	0.3	5.7	Chatterjee, 1956 (17)
		C			0.3			5.0	0.4	3.5		0.9		Esh, 1953, 1954 (22)
		M			0.5				1.0			0.2		Gupta, 1955 (25)
		M	8.9	2.2		4.4	6.9	6.4	0.7	4.5	3.5		4.8	Horn, 1955 (32)
		M			1.8			7.4	1.5			0.2		Jelliffe, 1956 (33)
		PC	8.5	3.8		6.3	10.9	8.0	0.7	6.3	4.5	1.2	5.4	Khan, 1957 (35)
		M	9.3	2.5		4.7	7.7	5.8	0.8	4.6	3.8	0.8	6.4	Raica, 1956 (55)
		M,C	7.0	2.2	0.8	5.5	5.4	5.8	0.8	4.1	2.9	0.3	5.3	Vijayaraghavan, 1953 (67)
Lupinus albus	white lupine	PC	8.3	3.0	1.0	—10.9—		5.2	1.8	5.1	7.3	0.8	3.7	Hanson, 1953 (26)
		PC	9.5	2.4	1.3	—12.0—		4.4	1.6	5.1	4.5	1.0	3.7	Nehring, 1957 (51)
Lupinus angustifolius	blue lupine	M	8.4	2.5		5.0	6.1	4.5	0.4	3.9	3.4		4.1	Dunn, 1948 (20)
		C			1.8				0.5					Lugg, 1944 (42)
		PC	9.3	2.4	1.1	—11.8—		4.6	0.8	4.0	3.7	1.0	4.3	Nehring, 1957 (51)
Lupinus luteus	yellow lupine	M	6.2	1.9	0.7	3.7	7.5	3.8	1.0	3.9	2.0	1.0	4.6	Ågren, 1949 (4)
		C			2.8				0.6			0.7		Lugg, 1945 (41)
[4]		PC	6.5	2.1	0.7	—13.6—		4.1	1.1		2.4	0.8	5.2	Nehring, 1957 (51)
Lupinus pilosus		PC	11.7	5.9		7.3	11.1	6.3	1.9	7.5	4.5	2.2	7.4	Holmes, 1951 (31)
		C			1.9				0.7					Lugg, 1944 (42)

Phaseolus aconitifolius	aconite bean	M		3.3	0.5	4.9	6.7	5.4	0.9	4.5		0.7	3.1	Deshpande, 1954 (19)
Phaseolus aureus	mung bean; green gram	M				8.2	4.8	6.8	1.2	6.0	3.5	1.0	6.0	Baptist, 1954 (10)
		M			0.2				2.1			0.3		Gupta, 1955 (25)
		M			1.2			4.5	0.7			0.8		Jelliffe, 1956 (33)
Phaseolus lunatus	lima bean	M	6.4	3.0		5.6	8.2	7.6	1.2	5.6	4.8		5.8	Horn, 1955 (32)
[4]		M	6.7	3.4		6.6	7.7	6.5	1.0	4.8	4.2	1.2	6.3	Murphy, 1957 (47)
		M	6.1	3.4		6.0	8.3	5.9	1.5	6.2	4.7	0.9	7.8	Raica, 1956 (55)
		M			1.8			6.7	1.7			0.7		Jelliffe, 1956 (33)
Phaseolus mungo[15]	black gram; urd	M				4.9	8.8	6.7	1.5	5.8	3.5	1.0	6.0	Baptist, 1954 (10)
		M	7.5	2.0		7.3	10.2	7.3	1.5	5.3	3.4	0.4	6.9	Chatterjee, 1956 (17)
		M,C	9.6	3.8		4.5	5.3	4.7	2.1	4.0	2.9	0.7	3.4	Chitre, 1956 (18)
		C			0.7			5.2	0.8	3.8		1.3		Esh, 1953, 1954 (22)
		M			0.4				3.3			0.3		Gupta, 1955 (25)
		M			1.3			7.7	2.2			0.9		Jelliffe, 1956 (33)
		PC	5.2	3.3		5.8	10.5	6.8	1.1	6.3	3.9	1.4	5.6	Khan, 1957 (35)
		M,C	5.7	2.7	0.7	5.5	7.2	6.0	1.1	5.4	4.3	0.5	6.4	Vijayaraghavan, 1953 (67)
Phaseolus radiatus (=*P. mungo*) [15]	green gram	M	10.2	2.5		9.9	12.4	9.2	1.3	5.7	4.1	0.5	8.5	Chatterjee, 1956 (17)
		M,C	11.9	4.3		5.2	7.5	6.9	3.0	3.8	2.8	0.6	4.5	Chitre, 1956 (18)
		C			0.4			8.0	0.9	3.5		1.0		Esh, 1953, 1954 (22)
		M			1.2			7.8	2.5			0.9		Jelliffe, 1956 (32)
		PC	4.4	4.1		7.0	12.9	7.9	0.8	7.1	4.5	1.4	6.2	Khan, 1957 (35)
		M,C	6.3	2.7	0.6	6.3	7.7	7.0	1.0	5.9	3.5	0.5	6.4	Vijayaraghavan, 1953 (67)
Phaseolus vulgaris	kidney bean; navy bean; pinto bean	M	6.9	2.8		5.1	4.9	7.1	1.2	5.3	4.8	1.4	5.5	Lyman, 1956 (43)
		M			1.1			7.4	1.9			0.5		Jelliffe, 1956 (33)
		M	5.4	2.9		5.7	8.2	6.8	1.0	6.1	4.3	1.0	6.2	Hirsch, 1952 (29)
[4]		M	6.6	2.8		5.0	7.8	7.7	1.2	6.0	4.9		6.1	Horn, 1955 (32)
		M	5.3	3.1		5.5	9.2	7.2	1.2	6.5	4.5	1.1	7.1	Raica, 1956 (55)
[2]		M						8.2	1.0			0.7		Tandon, 1957 (65)
		M	5.9	2.4		4.9	7.7	9.2	1.0	5.3	3.5	1.1	5.9	Williams, 1955 (70)
[2]		M	5.4	3.2		6.3	8.4	7.2	2.8	5.6	4.8		5.7	Lantz, 1958 (40)
Pisum sativum	pea	M	7.2	3.2	1.5	5.3	6.4	6.2	1.5	5.0	3.8	1.2	5.2	Edwards, 1955 (21)
		C		0.5				7.0	0.3	3.6		1.1		Esh, 1953, 1954 (22)
		M		0.5					1.2			0.2		Gupta, 1955 (25)
		PC	10.7	4.6		4.8	7.9	8.1	1.7	5.7	4.1	2.0	4.1	Holmes, 1953 (31)
		M	9.7	2.3		4.6	7.5	7.5	0.8	4.8	3.9		4.9	Horn, 1955 (32)
		M	5.1	2.7		5.6	6.1	5.6	0.8	4.0	3.8	1.0	5.8	Murphy, 1957 (47)
		M	13.4	2.1		7.1	9.5	8.9	0.8	4.6	4.2	0.3	6.5	Chatterjee, 1956 (17)

Botanical Name	Common Name	Method of Anal.[1]	Percent amino acid in protein (16% N basis) Argi-nine	Histi-dine	Cystine	Isoleu-cine	Leu-cine	Lysine	Methi-onine	Phenyl-alanine	Thre-onine	Trypto-phan	Valine	Author, Reference
[11]		PC	7.6	1.6	1.0	—11.6—		5.7	1.3	4.5	3.7	1.2	4.5	Nehring, 1957 (51)
		M	17.7	2.7		8.4	10.9	11.4	1.3	5.8	4.9	0.7	7.8	Ramachandran, 1956 (56)
		M	10.6	2.4		5.0	8.0	6.9	0.8	5.0	4.0	1.0	5.8	Raica, 1956 (55)
Trifolium subterraneum	subterranean clover	PC	11.7	3.2		2.7	4.6	9.2	1.5	3.6	1.8	1.9	4.0	Holmes, 1953 (31)
		C			0.6				0.6			1.0		Lugg, 1945 (42)
Trigonella foenum-graecum	fenugreek	P	8.0	1.1		—11.0—		8.0	[16]	1.0	5.0		[16]	Kolousek, 1955 (39)
Vicia faba	broad bean; horse bean	M	6.2	2.9		5.6	7.6	5.6	0.5	3.4	2.6	0.9	5.1	Khan, 1957 (35)
		PC	7.5	3.3		6.2	10.3	6.7	0.6	5.4	4.4	1.0	5.5	
		M	5.9	2.9	1.2	5.5	7.6	5.5	0.5	3.4	2.6	0.9	5.1	Mahon, 1950 (44)
		M	7.9	1.8		7.0	9.8	5.7	0.3	4.9	3.9	1.0	4.9	Massieu, 1950 (45)
Vicia hirsuta	vetch	M			0.5				0.9			0.3		Gupta, 1955 (25)
Vicia sativa	vetch	PC	12.3	5.3		5.7	7.2	5.7	2.6	7.7	5.2	1.0	7.9	Holmes, 1953 (31)
			9.9	1.3	1.1			3.2				0.8		Yaichnikov, 1954 (72)
		M			0.4				0.9			0.4		Gupta, 1955 (25)
Vigna catjang	black eyed pea;	M			1.5			5.7	1.8			0.6		Jelliffe, 1956 (33)
(=*V. cylindrica*)	cowpea	M	6.8	3.1	0.7	4.9	7.5	6.2	1.0	5.2	3.3	0.6	6.3	Vijayaraghavan, 1953 (67)
Vigna sinensis	black eyed pea; cowpea	M	6.2	3.2		4.7	7.2	6.3	1.3	5.2	3.8	1.0	5.5	Hirsch, 1953 (29)
		PC	7.0	3.3		6.2	11.3	6.5	0.9	6.0	5.3	1.3	4.9	Khan, 1957 (35)
		M	5.3	3.0		4.7	7.2	6.3	1.2	5.2	4.3	1.3	5.6	Lyman, 1956 (43)
		M	7.7	3.2		5.9	7.7	6.9	1.4	5.6	3.7	1.3	6.4	Murphy, 1957 (47)
14. Linaceae (Flax family)														
Linum usitatissimum[2]	linseed; flax		9.4	2.2	1.5	5.0	6.4	3.5	1.6	4.6	4.1	1.4	5.1	Block, 1956 (15)
		M	9.3	1.8		4.6	6.0	3.6	1.7	4.5	3.8	1.7	5.6	Lyman, 1956 (43)
		PC	7.9	1.3	1.5	—11.4—		2.7	2.6	4.9	4.2		7.4	Nehring, 1957 (51)
					1.9				2.3			1.6		Bergh, 1952 (14)
15. Malvaceae (Mallow family)														
Gossypium sp.[2]	cotton		12.1	2.7	1.6	3.6	5.7	4.4	1.4	5.4	3.4	1.3	4.6	Block, 1956 (15)
		M	11.0	2.7		4.0	6.2	4.2	1.5	5.3	3.5	1.6	5.0	Lyman, 1956 (43)
		C			2.0				1.6			1.3		Bergh, 1952 (14)
Hibiscus cannabinus	kenaf	M	15.0	2.2		4.0	6.1	5.6	1.0	4.1	3.0		5.5	Authors' Unpublished data

16. Moraceae (Mulberry family)														
Artocarpus itegriflora	jack seed	M	1.9	1.0	1.4	7.2	7.9	4.8	1.4	7.7	5.8	1.3	8.8	Baptist, 1954 (9)
Brosimum alicastrum	bread nut	M	7.8	1.3		4.8	9.2	3.7	0.5	4.0	3.3	2.3	8.2	Massieu, 1950 (45)
17. Moringaceae														
Moringa pterygosperma	drumstick bean	M	3.6	1.1	2.7	4.3	6.4	1.5	1.4	4.3	4.9	0.8	5.4	Baptist, 1954 (9)
18. Papaveraceae (Poppy family)														
Papaver sp.	poppy	PC	7.3	1.7	1.3	—11.9—		3.9		4.5		1.1	7.7	Nehring, 1957 (51)
19. Pedaliaceae														
Sesamum indicum[2]	sesame		8.1	1.5	1.3	4.8	8.0	2.7	3.3	7.4	3.1	2.0	5.1	Block, 1956 (15)
		M	11.9	2.2		4.3	6.9	2.8	2.7	4.7	3.6	1.9	5.1	Lyman, 1956 (43)
		PC	9.2	1.8	1.4	—12.7—		2.7	2.9	7.1	5.0	1.4	5.6	Nehring, 1957 (51)
		M	10.0	2.4		3.6	6.1	2.7	2.0	4.5	3.5	1.2	4.8	Williams, 1955 (70)
20. Polygonaceae (Buckwheat family)														
Fagopyrum esculentum	buckwheat	CC	7.9	3.0		5.4	7.4	5.7	2.1	4.2	5.0	1.3	6.3	Kimura, 1956 (36)
		M	9.5	2.2		3.5	5.2	5.6	1.9	3.8	4.2	1.7	4.7	Lyman, 1956 (43)
21. Rosaceae (Rose family)														
Prunus amygdalus	almond	M	10.1	2.3		3.9	6.5	2.6	1.2	5.1	2.7	0.8	5.0	Raica, 1956 (55)
22. Sapotaceae														
Butyrospermum parkii	shea nut; karite	C	8.2		1.0		9.9			2.9		1.1	1.4	Roche, 1946 (58)
23. Sterculiaceae														
Theobroma bicolor		M	9.3	1.5		4.6	8.7	4.9	0.6	5.8	3.3	1.3	5.3	Massieu, 1950 (45)
24. Umbelliferae (Parsley family)														
Anethum graveolens	dill	M	7.9	2.0		4.8	5.8	6.5	0.9	4.3	3.6		7.0	Authors' Unpublished data
Daucus carota	carrot, Queen Anne's lace	M	6.2	2.5		5.9	6.5	6.6	1.4	5.1	3.5		7.2	Authors' Unpublished data
25. Vitaceae (Vine family)														
Vitis vinifera	grape	C	4.9		2.4		11.4			4.2			2.4	Roche, 1946 (58)

[1] M=microbiological; C=chemical; PC=paper chromatographic; CC=column chromatographic [2] Average values [3] Average of 4 varieties [4] Average of 2 varieties [5] Average of 9 varieties [6] Average of 3 varieties [7] Average of 2 wild varieties [8] Average of 3 cultivated varieties [9] Average of 5 varieties [10] Average of 7 varieties [11] Average of 3 varieties [12] Ramakrishnan reported this data under the name *C. psoralioides* [13] Valine + methionine, 12.0% [14] Basis of calculations in some doubt. [15] According to the best authorities, *P. radiatus* is a synonym of *P. mungo*. Owing to the large number of analyses published under each name, these are listed separately. [16] Valine + methionine. 6.0%.

neae, however, rank relatively high in methionine content. The characteristic of high methionine and low lysine is shared by two other families—the Pedaliaceae represented in this survey only by sesame (*Sesamum indicum*), and the Lecythidaceae, represented by the Brazil nut (*Bertholletia excelsa*). The latter has been reported by Raica and coworkers (55) to contain 5.5% methionine in its protein, the highest value in the present tabulation for this frequently deficient amino acid.

Advantage may be taken of the relative abundance of one particular amino acid in certain vegetable proteins by the use of combinations in which a mutually supplementary effect is achieved. Combinations of corn, deficient in lysine, with soybeans, deficient in methionine, are common in feedstuffs. A combination of soybean and sesame was shown to be an excellent protein source, because the former is relatively rich in lysine and the latter in methionine (5). Other seed proteins which will be useful as protein supplements because of an exceedingly high content of lysine, methionine, or some other essential amino acid may conceivably be found.

The Compositae, which include sunflower (*Helianthus annuus*) and safflower (*Carthamus tinctorius*) are inferior to the legumes in lysine content but, on the average, have about the same percentage of methionine in their protein. The Cruciferae, of which rape (*Brassica rapa* and other species) is the leading oilseed representative, are also inferior to the legumes in lysine content but are somewhat richer in methionine. The Euphorbiaceae (e.g. castor bean, *Ricinus communis*) are even lower, on the average, than the crucifers in lysine content but are somewhat higher than the legumes in methionine. Seeds of the Cucurbitaceae (e.g. pumpkin, gourds) appear to be rather low, on the average, in both lysine and methionine.

These generalizations may be strengthened or discredited by future findings. In any case, it is anticipated that definite exceptions will appear to general trends within any given family. Also, a certain amount of variability is apt to occur in amino acid composition even within one species, as is illustrated, for example, by the work of Wolfe and Fowden (71) on different varieties of maize. The approach used here may be fruitful in systematizing a search for seed proteins of superior nutritional quality.

Total Protein Content and Crop Potential of Various Plant Families

Table II shows the ranges of seed protein content reported in the literature as occurring among the various plant families represented. As in the case of the amino acid composition, "average" values were calculated. As mentioned, such values have the advantage of serving as aids in formulating generalizations and correlations, but these averages are subject to limitations as to the rigidity of conclusions that can be drawn. For example, the protein content of legume seeds is generally higher than that of grass seeds, yet in Table II as little as 10-15% protein is listed for seeds of some legume species while up to 25-30% is indicated for selected grass seeds. A screening program is concerned with both types of situations—general trends and exceptions to the trends. Systematic search for promising new species must take cognizance of indicated generalities based on previous investigations and analyses. However, alertness to exceptions may reveal species of outstanding value in a chemical compositional aspect completely unique to its botanical category.

The various plant families have also been rated in Table II according to their potentialities as protein-producing seed crops in the continental United States.

Correlations and Evaluations. An attempt was made to correlate botanical relationships with protein composition with regard to selected amino acids. For example, the "average" lysine and methionine content of the seeds of each species (on a percentage of protein basis) was calculated from data in Table I. These resulting "averages" were, in turn, used to calculate an over-all "average" for the methionine and lysine content of the various plant families. Generalizations given are based on these calculated values. The authors are well aware of the limitations of this approach because (a) numerous families are represented by but a single species which is not necessarily typical of the entire family, and (b) in some cases there is considerable variation among reported values for amino acid composition of seed proteins *within* a family. Yet there is a fair consistency within families, and until further data on composition of plant proteins are obtained, one can only compare the considerable differences among plant families as revealed by existing information.

Tentative indications on the basis of present data place the Amaranthaceae (e.g. pigweed, tumbleweed) highest in lysine (8.2% of the protein) and third highest in methionine content (2.5%). These figures rest primarily on analyses of one species (*Amaranthus paniculatus*) by a single group of workers—Ramachandran and Phansalkar (56). Prior to their publication, it had been reported by Subramanian and Srinivasan (64) that according to their feeding experiments seeds of *Amaranthus paniculatus* had a protein efficiency comparable to casein. Confirmation of these extraordinary findings is needed.

Second highest in lysine content are the Umbelliferae, which contain an average of 6.6% of the total protein. Apparently this is the first report on the amino acid composition of seeds of this family. The Leguminosae and Chenopodiaceae are next in lysine content with 6.3%. Two *Chenopodium* species, which are grain crops in the Peruvian Andes and belong to the family Chenopodiaceae, have been the subject of recent publications by White and coworkers (69) and by Quiros-Perez and Elvehjem (54). Rat-feeding experiments have indicated that seeds of this genus have high protein quality in accord with the high lysine and methionine content indicated (see Table I).

Such singular instances of seed proteins distinctly superior in nutritional quality to those commonly consumed should give impetus to efforts to discover other superior protein sources in plant families as yet little examined in the chemical laboratory, even though the cases mentioned here may in themselves be of little more than academic interest because the *total* protein content of these seeds is not very high.

Legumes generally are good sources of lysine, though undesirably low in methionine content. Because total protein content in legumes is generally high, they afford important dietary sources of protein for large sections of the world's population. An exception to the generally high lysine content among the 29 legumes tabulated is furnished by peanut (*Arachis hypogaea*), which contains only *ca.* 3.5 g./16 g. N.

The family Polygonaceae, represented in this tabulation only by buckwheat (*Fagopyrum esculentum*), is fourth highest in lysine content with an average of 5.7% of the protein. Although buckwheat is commonly referred to as a grain, it belongs to a different family from the common cereal grains—the Gramineae, or grass family—and it produces protein of considerably better amino acid balance than the protein in grass seeds, which are among the lowest in average lysine content (*ca.* 3.0% of protein). Seed proteins in the Grami-

Family	Number of Species Reported	Number of species having protein percentages in the indicated ranges										"Average" Percent Protein	Rating as Potential Protein Source[1]
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70		
Pinaceae	3		2					1						16.9	D
Tiliaceae	2			1		1								16.7	D
Meliaceae	8		2	1	3	1	1							16.3	D
Plantaginaceae	3			1	2									16.2	C
Saxifragaceae	1				1									15.0	U
Lauraceae	3		2					1						14.9	D
Sapindaceae	10		2	3	4	1								14.6	D
Auraucariaceae	1			1										14.6	D
Sterculiaceae	10		3	2	4	1								14.5	D
Caryophyllaceae	2			1	1									14.5	C
Burseraceae	6			4	2									14.4	D
Corylaceae	3	1	1	1										14.0	C
Myristicaceae	2			1	1									14.0	U
Gramineae	41		7	21	9	3	1							13.8	C
Umbelliferae	1			1										13.8	B
Vitaceae	2		1		1									13.7	D
Orobranchaceae	1			1										13.5	D
Onagraceae	1			1										13.4	U
Staphyleaceae	1			1										12.9	U
Rubiaceae	7			7										12.7	U
Chenopodiaceae	3			3										12.5	B
Oleaceae	1			1										12.2	U
Celastraceae	1			1										12.1	U
Santalaceae	1			1										12.1	U
Ginkgoaceae	1			1										12.0	D
Apocynaceae	3	1			2									11.9	D
Fagaceae	7	1	3	1		2								11.9	D
Hydrocaryaceae	2	1			1									11.6	D
Polygonaceae	1			1										11.3	B
Simarubaceae	4		2	1	1									11.3	D
Ranunculaceae	1			1										10.9	U
Palmaceae	13		9	2		2								9.7	D
Magnoliaceae	1		1											9.1	D
Cycadaceae	2	1		1										8.9	D
Proteaceae	1		1											8.6	U
Sapotaceae	6		5	1										8.0	D
Valerianaceae	1		1											8.0	U
Vochysiaceae	1		1											7.9	U
Hippocastanaceae	2		2											7.3	D
Dipterocarpaceae	1		1											5.7	D
Guttiferae	8	3	5											5.5	U
Cactaceae	1	1												3.9	D

[1] See text.

TABLE II

PROTEIN CONTENT AND RATING AS POTENTIAL SEED CROPS OF SEEDS FROM VARIOUS PLANT FAMILIES

Family	Number of Species Reported	Number of species having protein percentages in the indicated ranges												"Average" Percent Protein	Rating as Potential Protein Source[1]
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70		
Moringaceae	1										1			46.6	U
Ulmaceae	3								1	2				40.1	D
Bignoniaceae	1							1						32.8	U
Leguminosae	87			3	6	25	16	12	11	7	2	3	2	30.1	A
Zygophyllaceae	1						1							29.8	U
Asclepiadaceae	4					1		2	1					29.0	C
Cucurbitaceae	17			1	1	4	2	6	2	1				28.3	A
Combretaceae	1						1							27.9	D
Caricaceae	1						1							27.2	U
Cannabinaceae	2					1		1						27.0	D
Aceraceae	4					1	3							27.0	D
Linaceae	1						1							27.0	B
Rhizophoraceae	1						1							26.4	U
Bombacaceae	5				1		2	2						26.0	D
Compositae	11				4	3		1	1	2				25.9	A
Capparidaceae	3			1			1		1					25.4	B
Moraceae	2			1					1					25.0	U
Cruciferae	8				2	3	1	2						24.9	A
Martyniaceae	1					1								24.4	U
Rutaceae	5				3	1					1			24.3	D
Pedaliaceae	1					1								22.9	B
Euphorbiaceae	27		1	1	8	7	8	1			1			22.7	B
Balsaminaceae	2					2								22.6	C
Labiatae	5					5								22.2	B
Ericaceae	3				1	2								21.5	C
Rosaceae	15		2	3	1	3	4		2					21.5	C
Papaveraceae	1					1								20.9	B
Malvaceae	9	1			1	7								20.2	B
Typhaceae	1				1									19.8	D
Solanaceae	4		1		1	1	1							19.4	B
Anacardiaceae	4		1		1	1	1							19.3	D
Lecythidaceae	2				1	1								19.1	D
Olacaceae	2				2									18.6	U
Juglandaceae	4		1	1		1	1							18.2	D
Annonaceae	4	1			1		2							17.8	D
Flacourtiaceae	6			2	2	2								17.8	D
Nymphaeaceae	1				1									17.7	D
Amaranthaceae	3				3									17.4	B
Dipsacaceae	1				1									17.0	U

these extremely high-protein species are herbaceous but have not attracted attention as seed crops and may therefore afford possibilities for new crop developments. Some of the species having 40% or more protein in their seeds are: *Clitoria ternatea, Crotalaria juncea,* various species of *Lupinus* and *Medicago, Sesbania grandiflora,* and *Trifolium subterraneum.* Others in this very high-protein group are tropical trees or otherwise unattractive agriculturally in the United States.

Rape is currently the best-known oilseed member of the crucifer family; there has also been some interest in Montana in mustard as a seed crop (34, 66). The relatively high protein content of crucifer seeds as a whole, averaging about 25%, and their relatively high oil content (18-45%) suggest that the crucifer family may be a rewarding field for exploration for protein sources.

The Compositae include two oilseed crops of some significance—safflower (*Carthamus tinctorius*) and sunflower (*Helianthus annuus*). In view of the relatively high protein content and oil content (*ca.* 30-40%) of the composite seeds, it appears this large and varied family is worthy of considerable investigation in a search for new and better protein sources. From present indications, however, it would not be anticipated that proteins of superior nutritional quality would be found in this family.

On the whole, seeds of plants in the Cucurbitaceae, or gourd family, are outstandingly high in protein (average *ca.* 28%) and in oil (often 40-60%). No presently important seed crop is a member of the cucurbit family, partly because of the viny habit of its members. The data suggest that the cucurbits warrant further attention as potential protein-rich seed crops. Again, the expectations for protein of high nutritional quality are rather scant.

Among families which appear on the basis of existing data to show some promise as protein sources should be mentioned the Euphorbiaceae and Malvaceae. Cottonseed is of considerable economic importance as a byproduct of cotton fiber, but seeds of the Malvaceae as a whole are not recorded as being notably high in protein or oil content, nor does their average amino acid composition add to interest in them.

Most seeds of the Euphorbiaceae are relatively high in protein and oil. The castor bean (*Ricinus communis*) is presently exploited for its oil, but unfortunately a toxic protein factor (62) seriously interferes with the use of the residual meal as a feed.

The exceptionally high-quality protein indicated for certain of the Chenopodiaceae, Polygonaceae, and Amaranthaceae has been alluded to previously. Members of these families which have been analyzed are unfortunately rather low in protein. Screening of other species in these families possibly might reveal some having higher seed protein content, possibly also of good quality.

The Umbelliferae are a family with moderate seed protein content (*ca.* 16-28%), judging from published figures and the authors' unpublished data. In view of the relatively high lysine content in their proteins as indicated by our preliminary results, it is suggested that species in this family merit consideration and further investigation. *Daucus carota* (wild carrot) is a successful weed in many areas and presumably could be rather easily adapted to cultivation.

Flax (*Linum usitatissimum*) and sesame (*Sesamum indicum*), which have some prominence as oilseed crops and protein sources, are the only well-known representatives of their respective families—the Linaceae and Pedaliaceae. Other species in these families should be screened as they become available for study. The little-examined Labiatae, or mint family, among which *Perilla frute-*

Because of the limited geographical area considered, it is not expected that the ratings assigned will be applicable worldwide. Ratings used were:

A—Most promising
B—Fair possibilities
C—Some possibilities
D—Unpromising
U—Insufficient data

Factors considered in these ratings included chemical compositional information on protein content and quality and the presence or absence of other constituents of probable value, particulary oil content. The ratings assigned also included consideration of agronomic characteristics. Assignment of agronomic ratings to individual species was based on the following specific criteria:

GROUP I. Terrestrial annuals or biennials and perennial herbs which can be harvested annually, which grow or can be grown in temperate to subtropical regions, which are upright in habit and a foot or more tall.

GROUP II. Terrestrial biennial and perennial herbs not seeding the first year, or the latter viny in habit.

GROUP III. Shrubs, small trees, and woody vines which are known to thrive in temperate to subtropical regions.

GROUP IV. Large trees known to thrive in areas of the United States, small trees and shrubs of warmer regions which are judged to be adaptable to limited areas in this country.

GROUP V. Perennials of the hot tropics, true aquatics, strict xerophytes, epiphytes, and parasites.

In addition to these criteria, the following general considerations were followed in making the agronomic ratings: The species was considered only as a source of seed; only crop environments of the continental United States were considered. Species judged to be adaptable to relatively large agricultural areas of the country were upgraded in comparison with those which would appear to be adaptable to relatively small areas; dioecious plants were considered less desirable than bisexual plants. Seed productivity, which is subject to improvement by the plant breeder and agronomist, was not evaluated.

The character of nonprotein constituents present, especially the oil, will no doubt have an important bearing on the possibility of economical production of protein concentrates from seeds under study. Whether the oil or carbohydrate gum constituents present add materially to the value of a new seed crop would depend, of course, upon whether they are uniquely desirable for industrial applications for which commodities now in abundant supply are unsuited. The likelihood of encountering such special properties among the nonprotein constituents of any given plant family is beyond the scope of this discussion, however. The ratings assigned are naturally affected by the fact that such a disproportionate number of the species analyzed for protein, about half of the total, occur in only 5 of the 81 plant families represented; namely, the Leguminosae, Gramineae, Euphorbiaceae, Rosaceae, and Cucurbitaceae. One-fourth of the total number investigated were legumes.

The literature data suggest that of the plant families considered, the Leguminosae, Compositae, Cruciferae, and Cucurbitaceae show the greatest promise for the development of high-protein vegetable sources. The legumes, in general, are low in oil, but a number are already important because of their high protein content and the high lysine content of this protein. The soybean (*Glycine max*), one of the most important legumes commercially, has been purposely bred to its present high content of oil, its most valuable constituent (62). A number of legumes have a seed protein content in the range of 40-60%, and two having protein content between 60 and 70% have been recorded. Some of

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scens has received some consideration as a potential oilseed crop, might be mentioned as a possible source of protein concentrates. The amino acid composition of *Perilla* protein appears to be mediocre from the nutritional point of view.

The Gramineae, which include the common cereal grains, undoubtedly are, and will continue to be, of great economic importance to mankind. However, the generally low protein content of grass seeds and the low lysine content of this protein make this family appear rather unpromising as a subject for investigating new sources of plant proteins. It should be noted that a disproportionate amount of our information on the grasses concerns the cereals in which, until very recently, starch has been the constituent of most concern.

As pointed out, data from Table II suggest that among those families for which we have a reasonable amount of information, the Leguminosae, Cruciferae, Cucurbitaceae, and Compositae are the most promising sources of proteins for the U. S. A. However, for many families, our information is too fragmentary to permit any evaluation of their protein potential. Until sufficient information is available on these families to furnish a basis for evaluation, they should continue to be of interest in a seed protein screening program.

Experimental Procedures

The amino acid composition of the seed proteins was determined by microbiological assay of acid hydrolyzates of the oil-free meals. A 200-mg. sample of each material was dispensed into a small test tube; 5 ml. of 2.5 *N* HCl was added with a pipet, the tube was sealed, and the hydrolysis of the sample was carried out in an autoclave at 121° for 16 hours. The hydrolyzates were adjusted with NaOH to pH 4.0 to aid precipitation of humin and filtered through fine sintered-glass filters to remove humin and extraneous material. The filtrates were further adjusted to pH 6.8 and the resultant clear hydrolyzates diluted to a volume appropriate for microbiological assay. Medium II as described by Sauberlich *et al.* (61) was employed; *Streptococcus faecalis* R (NRRL B-1295) was used for the threonine determination. The recommended medium VI of Steele *et al.* (63) was used for the remaining amino acid determinations and the assay organism was *Leuconostoc mesenteroides* P-60 (NRRL B-1116).

The tubes were incubated at 37° for 18-24 hours, and the growth of the organism was measured turbidimetrically.

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Utilization Abstract

Retamo Wax. Approximately half of the paper cited is devoted to the relatively little known retamo wax, which originates from *Bulnesia retama*, a member of the Zygophyllaceae. The plant is said to be abundant in parts of the provinces of Catamarca, La Rioja, Córdoba, Mendoza, San Luis and San Juan, mostly arid regions of western Argentina.

The authors believe that the physical, chemical and technological properties of retamo wax will make it useful in replacing carnauba, ouricurí and candelilla in many uses. Retamo wax is said to be excellent in shoe polishes and in waxes for wood, leather and metals; in making of carbon paper; in dyes for leather; in printers' ink; and in pharmaceuticals.

The potential annual production of retamo wax in Argentina is thought to be some 1,280 metric tons. The requirements of the Argentine market are given as about 145 tons a year; some 48 tons are used now. The trade name in the Argentine market is *Cera mimbi*.

The monthly production of retamo wax, in 1957, was said to have been fifteen metric tons. little more than enough to cover Argentina's potential internal requirements for a hard wax.

Origins, both botanical and geographical; methods of collection, preparation of material, and crude preparation of the wax; properties and characteristics of the wax; a short formulary; and uses and applications are given in the paper. There are a number of plates showing the retamo plant, its collection and preparation. José Claudio Tinto and Luis L. Pardo. *Revista de Investigaciones Forestales* *1*:71-121, ff. 33. 1957 —Louis O. Williams.

Living Telegraph Poles. Travelling from Stanleyville northward through the rainforest of the Congo basin toward Buta I noticed that the telegraph line parallel to the road was attached to living trees. I soon became aware that the telegraph pole trees were mostly all of the same species and too evenly spaced to have happened fortuitously.

The poles, in fact, are all planted and are *Ricinodendron Heudelotii* Pierre, a member of the Euphorbiaceae. The species is a fast-growing tree native in the secondary forests of the Belgian Congo and possibly also of Nigeria.

The telegraph poles are planted by cutting a six to ten meter pole from the forest and putting it in a hole at the desired place. During the rainy season the pole quickly strikes root and begins to put out branches and foliage. The telegraph wires are placed on the poles some six or more meters above the ground as soon as they are firm. The branches, which sprout at the summit of the poles, rarely interfere with the line.

The tree is useful as a living pole only in relatively wet tropical areas for it requires a wet, humid climate. —Louis O. Williams.

The Sago Palms and Other Food Plants of Marsh Dwellers in the South Pacific Islands

Some native groups of the South Pacific islands dwell in lowland swamps, an adverse environment for man. To ensure their sustenance, they rely on foraging for plants thriving naturally in the swamps such as sago palms (*Metroxylon spp.*) or the *Bruguiera* mangrove trees. Sometimes they grow plants adapted to the marsh conditions, such as *Cyrtosperma chamissonis*. The present work sums up the knowledge we have of these plants and their uses in Oceania.

JACQUES BARRAU*

Marshes occupy wide areas in the continental islands of the South West Pacific. Among the vegetation types prevailing in such an environment are the swamp forests. These are composed of mangrove trees (*Bruguiera, Ceriops* and *Rhizophora* spp.) where the water is brackish and of sago palms (*Metroxylon* spp.) or other species, such as *Terminalia brassii* Exell. in the Solomon Islands, where the water is fresh.

Needless to say, the possibilities of subsistence horticulture in these waterlogged surroundings are quite limited. Nevertheless, in some areas, for the most part in New Guinea, the marsh dwellers have evolved fairly elaborate techniques to grow the few edible plants which supplement their diet (Barrau, 1).

The purpose of the present article is to describe a few of the food plants characteristic of these swamp areas which are their natural habitat. As a matter of fact, some of these plants are the objects of foraging and not of proper cultivation.

The Sago Palms

The sago palms belong to the genus *Metroxylon* Rottböll. They are particularly abundant in the swampy lowlands of New Guinea where they form huge forests. The Papuans who live there use as a staple the starch which they extract from the stipe's pith.

The species of the genus *Metroxylon* are arborescent, monoecious palms, often more or less thorny. The columnar stipe reaches generally from 25 to 30 feet in height; the leaf petioles have a widened base clasping the stipe without ensheathing it. These are strong and, according to the species and varieties, either inerm or thorny. The leaflets are straight, acuminate, ensiform, with acerate margins which, in some cases, are spinulous. The inflorescence is an enormous raceme protruding at the tree's top from the center of the leaf crown. It appears at the end of the tree's life. The lowest part of the primary ramification of this inflorescence is ensheathed in a tubular spathe, as are the secondary ramifications which bear alternate catkin-like spikes on which are densely grouped the flowers set out by pairs—one male and one female—in a spiral. These flowers have membranous bracts and villous bracteoles, the latter being sometimes reduced to a tuft of hairs. The fruit—globulous, turbinate, egg-shaped or pyriform, according to the species and variety—is covered with scales set out in vertical series and contains a seed often hard enough to be used as a source of vegetable ivory.

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FIG. 2. Flowering *Metroxylon vitiense* in the collection of Naduruloulou Plant Introduction Gardens, Viti Levu Island, Fiji Group. (Photo J. Barrau).

M. salomonense Becc.
b) 5-6 cm. in diameter. base concave: *M. bougainvillense* Becc.

The map in Fig. 3 shows the distribution of these species in the South Pacific area.

Probably this classification is not entirely valid.

In the section *Eumetroxylon* (to which belong the two species, *M. rumphii* and *M. sagus*, frequently used as sustenance plants) Jumelle (3) draws the attention to the following fact: the fruits of *M. rumphii* or of *M. sagus* can give birth to seedlings either thornless or thorny. As a matter of interest, the Marind Papuans, who live in the swampy, most southern part of Netherlands New Guinea where huge stands of these species occur, claim that in any of the forests of thorny sago palm (*M. rumphii*) they have found thornless seedlings which they planted near the villages, thereby establishing groves of *M. sagus*. In this part of New Guinea, one can find among the wild sago palms all intermediate forms between a thorny *M. rumphii* and a thornless *M. sagus*. Beccari (2) himself wrote that the two species were "barely distinct."

Mention should be made that this author has at times described new species of *Metroxylon* on the basis of fragmentary specimens. Such was the case of his *M. upolense* of which, he wrote, he saw only *one* fruit.

Nevertheless, the sections he has erected on the basis of the number of scale series covering the fruit seem to be sound. However, *M. amicarum* raises another problem. Should this sago palm be kept in the genus *Metroxylon* or segregated from it and placed under the old generic name *Coelococcus*? Some botanists such as Kanehira (4) and Glassman (5) were apparently in favor of this segregation. The point is that the peculiar inflorescence of this palm and the fact that it bears fruits during the tree's life differentiate this species from the others which have, as indicated above, an erected racemose inflorescence appearing at the top of the tree when it reaches the end of its life. Further investigation is needed to judge the exact value of this character as a possible criterion to segregate *M. amicarum* from the genus *Metroxylon*.

To complete this taxonomic discussion, one must mention that Burkill (6) suggested keeping in the old genus *Coelococcus* all sago palms growing in the South Pacific islands other than New Guinea. It is difficult to follow this proposal as the number of scale series of the fruit alone does not appear to be a sufficient criterion to do so.

The nomenclature presently used for the *Metroxylon* species is that of Beccari (2) who in 1918 described and classified all the then known forms of sago palms. If one follows this author, the *Metroxylon* species occurring in the islands of the South West Pacific are classified as follows:

A. Section *Eumetroxylon*: fruit covered with scales set out in 18 vertical series:

I. Petioles and spathes inerm: *M. sagus* Rottb. (syn. *M. inerme* Mart., *M. laeve* Mart., *Sagus genuina* Gisk., *S. inermis* Roxb., *S. laevis* Rumph.)

II. Petioles and spathes more or less thorny: *M. rumphii* Mart. (Syn. *Sagus genuina* Rumph., *S. rumphii* Willd., *S. spinosus* Roxb.)

B. Section *Coelococcus*: fruits covered with scales set out in 24-28 vertical series:

I. The inflorescence is not a raceme erected at the tree top, but axillary panicles appear between the petiole bases: *M. amicarum* Becc. (syn. *M. carolinense* Becc., *Coelococcus amicarum* Warb; *C. carolinensis* Dingl., *Sagus amicarum* Wendl.)

II. The inflorescence is a large raceme erected at the tree top.
  a) fruit obpyriform to turbinate
    i) 10-12 cm. in length, 7-8 cm. in width: *M. warburgii* Heim (syn. *Coelococcus warburgii* Heim).
    ii) 3-4 cm. in length, 2-3 cm. in width: *M. upolense* Becc.
  b) fruit globulous or egg-shaped. 5-6 cm. in length, 4-6 cm. in width: *M. vitiense*, Benth. & Hook. (syn *Coelococcus vitiensis* H. Wedl., *Sagus vitiensis* H. Wendl.)

III. Fruit globulous, more or less flattened down:
  a) 7 cm. in diameter—base not concave:

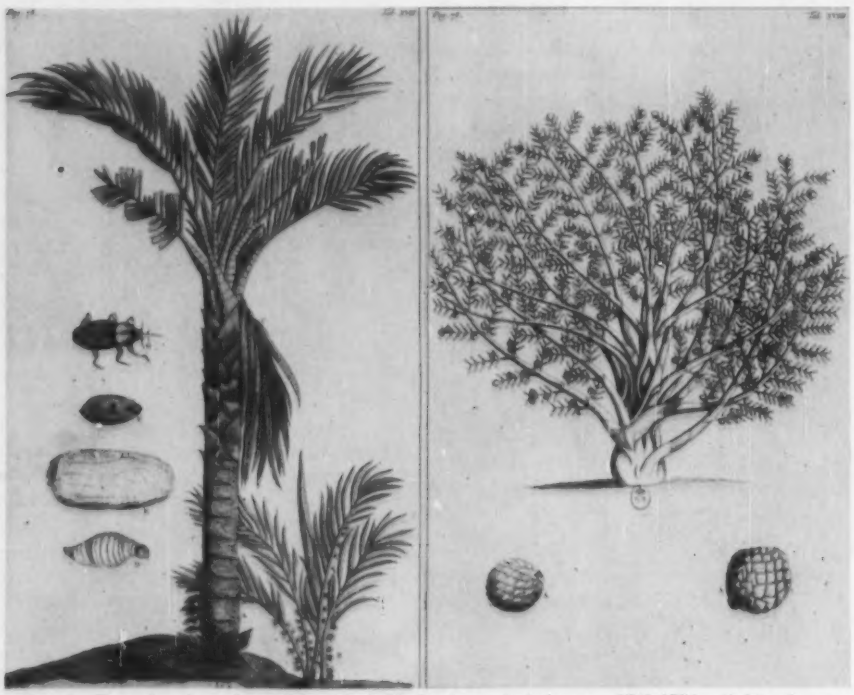


FIG. 1 Two drawings from Rumphius' *Herbarium Amboinense*, 1741-1756. (left) A sago palm with the adult and immature stages of a weevil which frequently attacks this species. Larvae found in rotten sago palm stipes are frequently eaten by the natives. (right) The inflorescence and fruits of sago palm. (Photograph Bibliothèque Nationale, Paris).

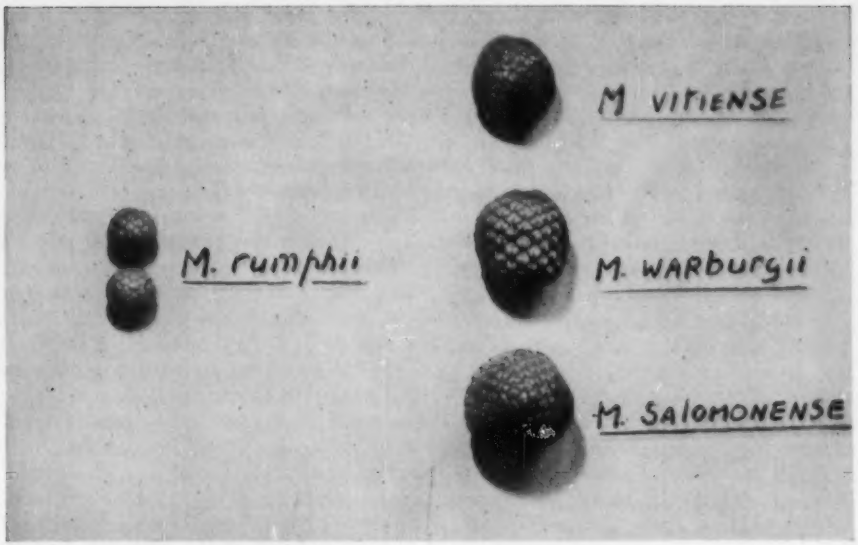


FIG. 4. Fruits of four species of *Metroxylon* found in the South Pacific islands. (Photo L. Devambez and J. Barrau).

Rembi, Rumbia and cognates in Indonesia.

It is mainly in New Guinea and the neighboring islands that varieties of *Metroxylon* are used for their starch content. In other territories where these palms exist, for some unknown reason their use as a food was discontinued long ago. Guppy (8) believed that the use of *Metroxylon vitiense* as a subsistence food was thus lost in Fiji. In the New Hebrides, where the people know only through tradition of this use of sago as food, today one comes across varieties of *Metroxylon* valued for their leaves only, which are used in house building. It is possible that in some distant epoch species of the *Metroxylon* group, whose center of origin spreads from Indonesia to New Guinea, were transported by men right to the borders of what is at present known as Polynesia.

In New Guinea, the islanders use the natural groves and also grow sago palms propagated by seedlings and suckers. Eight to fifteen years are required before the palm tree is worth felling, as it is just before flowering that the reserves of starch stored in the trunk are at their maximum. To prevent flowering exhausting these reserves, the Papuans occasionally remove the bud. Naturally sterile palm trees which accumulate enormous amounts of starch in their trunks are also found, and as much as 900 lbs. of crude sago has been extracted from such palms. This, however, is exceptional and the average yield is very much lower.

Mr. Zwollo, of the Department of Agriculture, Hollandia, Netherlands New Guinea, to whom I am indebted for much of my information on the sago palm, places the average yield at 250 to 350 pounds per tree. (Mr. Zwollo has produced for the Netherlands New Guinea administration a remarkable study, entitled "Sagoe Onderzoek," which is devoted to the sago palm and its uses.

Coming back to the distribution of the *Metroxylon* palms in the islands of the South West Pacific, it is of interest to underline the fact that species of the two sections *Eumetroxylon* and *Coelococcus* occur in New Guinea and the Bismarck Archipelago, where sago palms very similar to *M. salomonense* are found.

Beccari (2) was of the opinion that the *Metroxylon* has its center or origin in the Moluccas where another species, *M. squarrosum* Becc., occurs. It could very well be that this center includes the nearby sub-continent of New Guinea where huge natural forests of *Metroxylon* are found. Although we are far from knowing all the forms of *Metroxylon* occurring in this territory, present knowledge indicates that they are quite numerous and include a wide range of species and varieties (perhaps nearly all the species of *Metroxylon* described by Beccari).

In New Guinea, the sago palms are known under the following vernacular names: Abia, Aiasi, Akiri, Ambe, Api, Baiao, Balega, Barian, Da, Dou, Fi, Ipako, Na, Nafa, Ndana, No, Poï, Pu, Wariani. In the pidgin English used by the Papuans, they are called Saksak.

The natives of the New Hebrides called sago palms Natangora. On the island of Rotuma, its name is Ota or Oat, according to Bennett (7), while in the Fiji islands, it is Soqo or Soqa. The last name could be a local modification of Sago.

The sago palm is known as Lapia in the Moluccas, and as Rambia, Rembia,

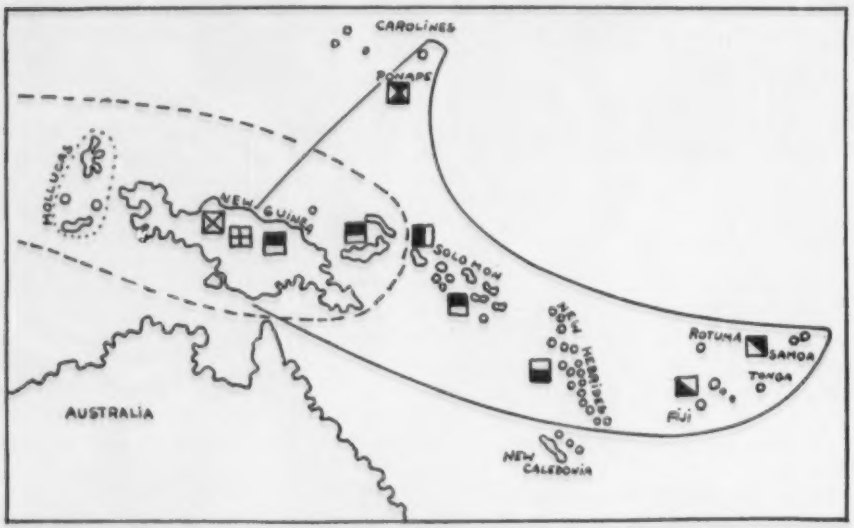


FIG. 3. Distribution of *Metroxylon* species in Oceania.

Unfortunately, this interesting work is unpublished.)

In a normal swamp forest grove there will be some 25 palm trees per acre per year which are worth felling. These will produce between 6,250 and 8,750 lbs. of crude starch, with a water content of between 35 and 40%, which represents roughly food value of 7,000,000 to 10,000,000 calories. *Metroxylon* yields however, vary considerably; certain varieties are particularly poor in starch, and it is possible to find dense groves of *Metroxylon* containing only trees with a very low sago production.

In a given area of swamp forest, the local people recognize a number of varieties of sago palms; for example, the Marinds of Netherlands New Guinea distinguish at least eight smooth or more or less thorny varieties with added variations in size, color, growth, and starch yield.

The starch or sago is extracted from the palms in the following manner. After felling, the bark is removed from half of the sago trunk. The pith is removed by grating and crushing with a kind of adze of which the cutting section is made of rough stone, hard wood, or more often, from a piece of sharpened bamboo. Today, where there is contact with the Europeans, a section of metal piping with sharpened edges is frequently substituted for the wood or stone tools.

The crushed pith is washed in an inclined trough, made from a leaf of the sago palm. This process is accompanied by threshing with a lath or kneading by hand. The liquid containing the starch runs into the trough, filters through a fibrous spathe arranged for this purpose, and is collected in draining pans made from portions of the palm (leaves, leaf stalks, etc.).

The drained sago is then partially dried and wrapped in bundles with palm leaves. These bundles vary in form but are most often cylindrical or conical. If the sago is intended for family consumption only, the bundles are more or less shapeless. Those intended for barter, however, are prepared with particular care. In New Guinea, the natives hollow out cylindrical holes in the fibrous residue left from the washing process and line them carefully with green *Metroxylon* leaves. They then heap the fresh starch into the hole, using it as a mould; and after wrapping the leaves over the top, they remove the package and bind it fast.

Bartering of sago gave the marsh dwellers in New Guinea the opportunity to procure articles which they lacked, such as pottery, tools, smoked fish, and other foods, notably tubers. This trade entailed real sea-going expeditions, such as those made by the natives of the Port Moresby district travelling to the western deltas to acquire supplies of sago. Even today, intensive canoe traffic continues to ply between the islands in the Geelvinck Bay and the Waropen marshes in Netherlands New Guinea.

Industrialized cultivation and commercialization of sago might afford a desirable improvement in the living conditions of natives inhabiting the swamp forests, where economic possibilities are limited. Although the starch produced by native methods is impure, it might well become an export product. As a matter of fact, a sago factory for export has recently been established in the Radja Empat Islands, in the most western part of Netherlands New Guinea. Additional evidence that this product can be of considerable export value is shown by the fact that in 1950 the United States imported some 6,000,000 lbs. of sago from Malaya and Indonesia.

In order to preserve the sago they produce, the natives find it sufficient to keep it damp in a covering of leaves, sprinkling it with water from time to time. Where pottery is known, the fresh

sago is merely placed in a large jar and covered with water. In some cases, a sago paste is made into briquettes, which are dried rapidly on the surface over a fire. These briquettes keep for about a month. As a general rule, the Papuans find that when sago is completely dried it loses its flavor. They consider the starch thus prepared by European methods as being practically inedible.

An examination of a number of food composition tables shows that sago consists almost entirely of starch and water (cf. Massal & Barrau, 9). The protein content is very low, in the region of 0.2 g. per 100 g.; fats are completely absent. Mineral salts are present only in very small quantities (ash, 0.35 mg. per 100; calcium, 10 mg.; phosphorus, 12.5 mg.; iron 1.5 mg.). There are practically no vitamins. Nevertheless, it is possible that the fermentation process which develops when sago is preserved in the wet state increases the vitamin B content. The water content of sago varies considerably depending on the methods of preservation used by the natives. The calorie value varies in relation to the water content and should be calculated according to the starch content of each sample.

In the South Pacific Commission labo-

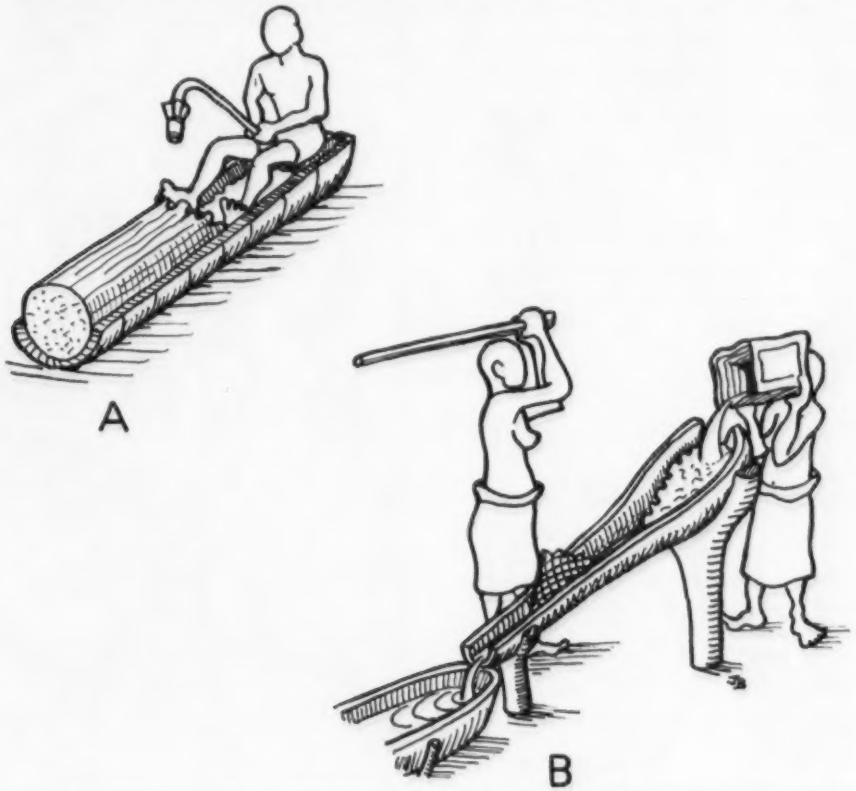


FIG. 5. Sago processing in New Guinea: (A) crushing the stipes pith; (B) Extracting the starch from the crushed pith. (Drawings by the author).

ratory in Nouméa, Mr. Frank Peters analyzed several samples of sago, or preparations made from sago, from Netherlands New Guinea. The results obtained and, in each case, the value of the constituent elements of the fresh and dried product, per 100 grams of the product, are given below.

All the samples were collected in Netherlands New Guinea.

These results call for no particular comment. They indicate clearly the variations in water content of sago preserved according to native methods and coincide with results already known.

Sago can only supply energy needs. In swamp regions of New Guinea where sago is the staple food, the average daily ration for an adult is about two lbs. This ration varies, according to Zwollo, from between 1½ to 3½ lbs. of raw sago and represents 1,700 to 4,000 calories. It is considered that, in order to satisfy its needs, the average family must spend around ten days per month in sago groves. As sago is an unbalanced foodstuff, it must necessarily be supplemented.

Within the ecological environment of the New Guinea swamp forest, animal and vegetable protein, fats, minerals and vitamins are supplied mainly by foraging. *Ipomoea aquatica* Forsk. leaves and other greens take the foremost place, while the products of fishing and hunting are of secondary importance. Fresh vegetables are grown on platforms or in the gardens on the limited areas above water. On the edge of the swamp forest or in savannah districts dotted with sago swamps, the diet is supplemented by tubers, roots, greens, and pulses from the gardens and by coconuts and by hunting.

Sago is eaten in various ways. Where pottery is known, a sago porridge accompanied by condiments and greens, fish, shellfish, or wild meat is the most popular form. Where pottery is not known, a kind of cake is generally made by cooking a sago paste, occasionally mixed with grated coconut, greens, fish, or meat in an oven of hot stones. This paste is cooked either rolled in green leaves, in half a coconut shell, or in a section of bamboo.

In districts of Netherlands New Guinea where pottery is used, a kind of biscuit, known in Malay as *sagoe lempeng*, which is easily preserved, is made in an earthenware mould which serves as an oven.

Thus, by exploiting natural or cultivated plantations of sago palms, the

Analysis of Sago Samples made in the South Pacific Commission Biochemistry Laboratory by Mr. F. E. Peters

Description	Water	Ash	Fibre	Starch (Acid Hydrol.)	Free Reducing Sugars	Ether Extract	Total Nitrogen	Nx625
Raw Sago	27.0	0.1	0.3	71.0	Nil.	Nil.	Trace	—
Sago Senole[a]	23.0	0.5	1.0	59.0	0.5	16.5	0.30	2.0
Sago Ega[b]	37.5	0.5	1.8	53.0	0.5	Nil.	0.1	0.5
	52.5	0.5	0.6	40.0	0.5	Nil.	Trace	—
Sago Lempeng[c]	12.0	0.3	0.2	84.0	Nil.	Nil.	Trace	—
Sago Bulu[d]	55.0	1.5	1.0	39.0	1.0	1.0	Trace	—
Sago Boengkoes[e]	42.0	0.5	0.5	53.0	0.2	2.0	Trace	—

a Common preparation made from a mixture of sago and grated coconut, shaped into a flat cake and baked.
b Sago paste preserved in briquette form, wrapped in sago leaves
c Sago biscuits
d Sago paste cooked in a green bamboo
e Roasted stick of sago paste

dwellers in the swamp forests of New Guinea obtain this energy food which is the basis of their diet. Moreover, through barter sago makes it possible for them to acquire a limited quantity of goods, local or imported, which are becoming daily more necessary for their existence in this ill-favored area.

It is scarcely possible to increase the food value of sago; supplementing of the diet seems to be reasonably assured by the natural resources. The living conditions of the swamp forest peoples of New Guinea could be improved by an industrialization and marketing of sago, as a source of revenue in these poverty-stricken areas.

The huge *Metroxylon* forests of New Guinea represent enormous potential resources in starch for export and industrial uses and deserve new research ranging from a botanical survey of the species and varieties to a study of the processing methods.

FIG. 6. *Cyrtosperma chamissonis* in a native garden of Ponape Island, Carolines Group, in Micronesia. (Photo. J. Barrau)

A Swamp Araceae with Edible Tuber —Cyrtosperma chamissonis (Schott) Merrill

The genus *Cyrtosperma* Griffith, Lasiae-Lasioïdae, Araceae, is a pantropical one whose wild species are found in Africa, Asia, Indonesia, and America. One species of *Cyrtosperma* is cultivated and is found mainly in the South Pacific islands and also in some localities of Indonesia and the Philippines.

Merrill (10) has rightly pointed out that the species, *Cyrtosperma chamissonis* (Schott) Merrill, while well known to botanists was one of those cultivated plants seldom mentioned in the literature of economic botany.

For a long time, there has been confusion in the nomenclature of this *Cyrtosperma* having been known as *Apeveoa esculenta* Moerenhout, *Arisacontis chamissonis* Schott, *Lasia merkusii* Hassk., *C. merkusii* (Hassk.) Schott, etc.

In 1914, Merrill (11) established the priority of the specific name *chamissonis* from *Arisacontis chamissonis* Schott, 1857.

The tendency of describing as new species the numerous cultivars of this species did not disappear for that. For instance, the *C. nadeaudianum* described by Moore in 1933 from a very fragmentary specimen from Raïatea Island, French Polynesia, is just one of these varieties. Today, in agriculturists' and even in economic botanists' reports on the Pacific islands, one can frequently find mention of *C. chamissonis* as *Alocasia* sp. or even *Xanthosoma* sp.!

C. chamissonis is a giant herb reaching up to 12 feet in height. It has large, erect, hastate-sagittate leaves of which the lobes, anterior and posterior, are almost equal in length. The long erected petioles are sometimes inerm but often thorny, with all intermediate stages between the thornless and thorny cultivars. The inflorescence is protected by a thick spathe, open its entire length and exceed-

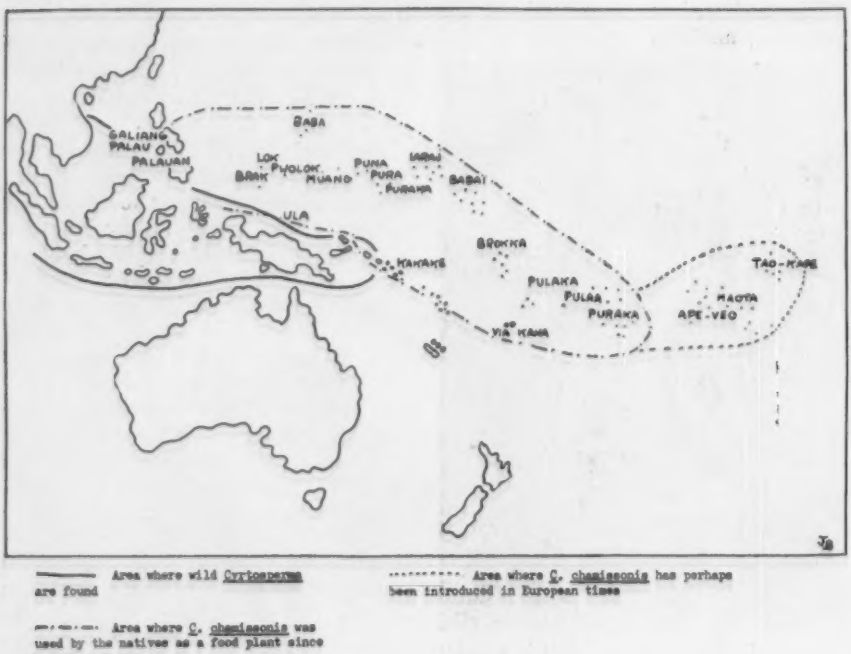
ing the length of the spadix. This spadix bears hermaphrodite flowers. The fruit is a berry and is fairly commonly seen on cultivated *Cyrtosperma* of this species. The seeds are frequently fertile. The tuber is large, short, and almost cylindrical.

The map (Fig. 7) shows the distribution of this species in the South Pacific area which probably has its home in the Indo-Malayan region—*sensu lato*—i.e. including New Guinea. In this area, many wild *Cyrtosperma* which seem related to *C. chamissonis* are found, the best known of them being *C. lasioïdes* Griffith.

On this map showing distribution of the species, the vernacular names of *C. chamissonis* have also been mentioned. Some of them are obvious cognates and the distribution seems to show that the migration which carried this plant to Polynesia reached that part of Oceania via the Micronesian Islands. The presence of *C. chamissonis* in New Guinea has not yet been recorded, and it has never been found in New Caledonia.

Many of the names of *C. chamissonis* seems to be related to the "biah," "birah," and "brak" which are used in Malaya to designate other edible Araceae such as *Alocasia macrorrhiza* Schott, biah being also used by the Semang negritos for the same species.

The vernacular names of *C. chamissonis* in what is now French Polynesia differ greatly and could be the signs of a fairly recent introduction of this species in these islands. The first naturalists who, during the 18th century visited Tahiti and the surrounding islands, did not mention the *Cyrtosperma* among the



——— Area where wild Cyrtosperma are found

·· ·· ·· Area where C. chamissonis has perhaps been introduced in European times

—·—·— Area where C. chamissonis was used by the natives as a food plant since pre-European times

FIG. 7. Distribution of *Cyrtosperma chamissonis* and its vernacular names in Oceania.

food plants which were then the subject of careful studies. It was only in the 19th century that, for the first time, the presence of *C. chamissonis* was recorded under vernacular names such as "ape-veo" or "tao-kape," the first meaning "yellow *Alocasia*" and the second "*Colocasia-Alocasia*." These combinations suggest that the islanders had no names for the plant, which was probably a newcomer and, in order to identify it, created composite vocables by taking the designations of traditional sustenance plants which resembled the *Cyrtosperma*.

Vegetative propagation is used by the Pacific islanders for the multiplication of *C. chamissonis*. In the Solomon Islands it is grown in natural swamps, and the same is true in some Polynesian high islands such as some of the Southern Cook Islands.

In the course of the migration across the Pacific, *C. chamissonis* was brought to islands where the conditions were adverse to its growth, such as the Micronesian and Polynesian atolls. There, mainly in Micronesia, the islanders recreate for the *Cyrtosperma* the environment of its natural habitat. In the Gilberts, amazing methods are thus used: a ditch is dug deep enough to reach the fresh-water lens and *Cyrtosperma* are planted in the mud at the bottom. As they grow, the islanders weave a basket around the plant and fill it with humus collected from beneath nearby undergrowth. This pot cultivation produces enormous tubers but takes several years, since the growth of *Cyrtosperma chamissonis* is slow.

Yield of old *Cyrtosperma* is sometimes enormous and can be higher than 100

FIG. 8 Woman peeling and washing *Bruguiera* fruits on Malaita Island, British Solomon Islands Protectorate. The sliced embryos are soaked in fresh water in the wooden bowl to eliminate tannin. (Photo. J. Barrau)

lbs. for one tuber, from a plant about ten years old. It is eaten roasted, steamed, or boiled with sometimes the addition of coconut cream. The composition of a *Cyrtosperma* tuber is said to be: 63% moisture, 34% starch, about 1.5% crude fiber and 1% ash with fats and protein accounting for the remaining 0.5% (Quisumbing 12).

A Mangrove With Edible Fruits—Bruguiera eriopetala

Among the mangrove species found in the coastal swamps of the South West Pacific islands, there is *Bruguiera eriopetala*, W. & Arn. (*B. gymnorrhiza* Koord. & Vallt., *B. sexangula* (Lour) Poir.). The fruit, whose seeds germinate while still on the tree, is foraged by the mangrove forest dwellers who use the embryo as food.

This mangrove tree is found in India, Tropical Asia, Indonesia, Melanesia, and Micronesia and is valued as a tanniferous plant.

The branches of *B. eriopetala* show scars of the fallen leaves. These leaves are pointed at the tip, and are brownish on their lower surface, while the upper is dark green and shiny. The axillary flowers, yellowish to orange, are 3 to 4 cm. in length, with a tubular calyx with 10 acute teeth, 10 caducous petals shorter than the calyx teeth, 20 stamens, and an ovary with a filiform style. The fruit, germinates on the tree, as indicated above, and gives birth to a radicle which can reach 20 cm. in length.

Tannin rich, the fruits have to be processed in a special way before being eaten. They are peeled, sliced, and soaked in water for several hours. They are then steamed or boiled and eaten with coconut cream. In the Loyalty Islands, the embryo is kept for months after sun-drying.

Heyne (13) mentioned a similar use of *Bruguiera* as a food plant in the Celebes.

The Pacific islanders call it aibon, wapa (Netherlands New Guinea), kua (Solomon Islands), doame, dowe, jadan, jeba, jecani, jen, jexa, jake, jigo, kan, kasou, ko, kibo, navo, nave, nusawe, wena (New Caledonia), dogo, togo (Fiji), ngengatz (Palau Islands) and lengatz (Yap Island).

CONCLUSION

In the field of economic botany, a lot remains to be done in the South Pacific islands. Wild plant species in this area are sometimes better known than the useful and cultivated ones. Sago palms offer an example of plants which will be worthwhile for further botanical and technological study.

The present article shows the limitations of the knowledge we have of such economic plants of Oceania and the usefulness of additional research in that field.

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